Q029-E-09 I 53.56: P87/2/FINAL/v.2

U.S. Department of the Interior
Bureau of Land Management
Wyoming State Office

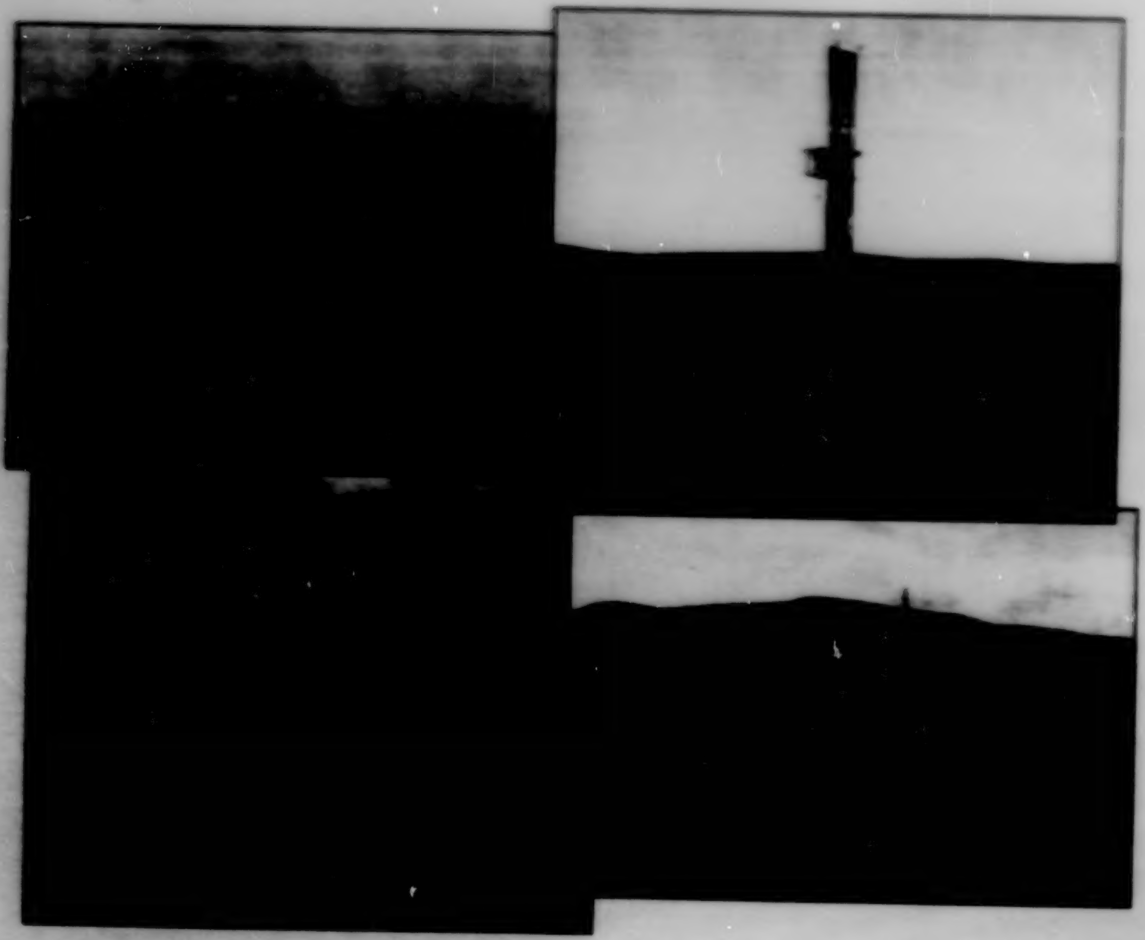
Buffalo Field Office

January 2003

Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project

Volume 2 of 4

(WY-070-02-065)



COMPLETED

MISSION STATEMENT

It is the mission of the Bureau of Land Management to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations.

BLM/WY/PL-03/004+1310

BEST COPY AVAILABLE

Chapter 4
Environmental Consequences

BLANK PAGE

Chapter 4 [illegible]

This chapter of the EIS provides an analysis of the effects (environmental consequences) that would result from implementation of the Proposed Action and alternatives. An environmental effect or consequence is defined as a modification or change in the existing environment brought about by the action taken. Effects can be direct, indirect, or cumulative and can be temporary (short term) or permanent (long term). Effects can vary in degree, ranging from only a slight discernable change to a drastic change in the environment. For this EIS, short-term effects are defined as occurring during the construction and drilling/completion phases. Long-term effects are caused by construction and operations that would remain longer.

The analysis evaluated the effects that would occur in the Project Area, regardless of land ownership. However, the decisions on this project by the BLM and FS would apply only to federal lands. The effects reported for non-federal lands may occur regardless of the BLM and FS' decisions. Effects on non-federal lands are included to provide a full disclosure of effects for the complete project and to support other environmental permitting associated with the project.

Groundwater

During development of CBM, a portion of the water contained in the coal aquifer is removed from CBM wells as produced water. The primary effects on groundwater resources would be associated with the removal of groundwater stored in coal seams and the subsequent recharge of aquifers through infiltration or injection of produced water. The combined effects of coal mining and other existing or reasonably foreseeable conditions on groundwater resources also are described within this chapter.

The effects of development of CBM on groundwater resources would be seen as a drop in the water level (drawdown) in nearby water wells completed in the developed coal aquifers and underlying or overlying sand aquifers. Drawdown is observed when a loss in hydraulic pressure head occurs in the developed coal aquifers or in the overlying and underlying sand aquifers. The hydraulic pressure head is the vertical distance between the water level in a water well and the top of the confined aquifer in which the well is completed.

Partial removal of groundwater from a coal seam (through coal mining operations or development of CBM) would reduce the hydraulic pressure head and create a hydraulic gradient toward the well or excavation. There would be a progressive decline in hydraulic pressure head with time and distance as groundwater flows into a pumping well or excavation. The effects would be seen as progressive declines in the water level (drawdown) within nearby water wells completed in and near the developed coal aquifers.

Leakage of groundwater from underlying and overlying units into the coal aquifer would initiate recovery in nearby water wells completed in the coal aquifer. Recovery would continue as CBM produced water that infiltrates the surface reaches the sand and coal aquifers. However, continued leakage of infiltrated produced water from overlying and underlying sands into the coals would delay noticeable recovery of the sands until removal of water ends. Water levels in nearby water wells would be expected to recover after removal of water ends. The rate of recovery initially would be rapid because of the re-equilibration of pressure heads within the coal and leakage from overlying and underlying units. The rate of recovery in the coal and sand aquifers would decrease progressively during the recovery period as the enhanced infiltration of produced water declines.

Other potential effects on existing water wells would include changes in water yield and quality or methane emissions. Other effects on groundwater resources would consist of potential changes in groundwater chemistry, in the nature of groundwater discharge to the surface, or recharge to the aquifers. The nature of groundwater discharge to the surface as springs, seeps, or base flows of surface drainages could change. Surface discharge of extracted groundwater from CBM operations into surface drainages, flow-through stock reservoirs, upland or bottomland infiltration impoundments, or upland containment impoundments would enhance recharge of shallow aquifers below creek and impoundment areas. Injection of CBM produced water would recharge the aquifer units in which the injection wells are completed.

Overview: Regional Groundwater Model

Hydrogeologic Groups

A detailed description of the geology and hydrology of the area is provided in Chapter 3. This analysis focuses on the coal seams of the upper part of the Fort Union Formation, the sands of the overlying Wasatch Formation, and the alluvium that underlies surface drainages.

The Wasatch Formation is exposed at the surface over most of the Project Area and overlies the Fort Union Formation. The Wasatch Formation consists of fine-grained sandstones, siltstones, claystones, and coals. The sandstones tend to be discontinuous but are used locally for water supply. Coal zones generally are not economic for mining or development of CBM, except in the area of Lake De Smet near the western margin of the PRB. Siltstones and claystones typically are of low permeability and form hydraulic confining units (or aquitards) within the Wasatch sequence.

The Fort Union Formation consists of coals, sandstones, siltstones, and claystones. The coals of the upper Fort Union Formation show great variation in thickness and continuity over the PRB. Coal seams split and merge over distances of a few miles so it is more appropriate to consider the coals as part of a hydrogeologic group rather than as individual aquifers. The upper sequence of the Fort Union Formation has been subdivided for this analysis into four hydrogeologic groups defined on the basis of the stratigraphic correlation of coal seams (Goolsby, Finley, and Associates 2000).

All four coal groups can be identified in the northern part of the PRB. Groups 1, 2, and 3 merge to form a thick coal unit, known as the Big George, in the central portion of the PRB. Only Group 4 is present in the southeastern part of the PRB, where it is locally known as the Wyodak coal. The outcrop areas of the coal seams are characterized by the presence of highly permeable clinker that forms a recharge area for the coal.

Assumptions for Groundwater

Recharge to groundwater aquifers occurs from direct infiltration of precipitation (rain and snowmelt), runoff in creek valleys, and standing water in playas. Infiltration is significant in areas of more permeable surface geologic units, such as sandstone or the clinker that occurs in outcrop areas of the Fort Union and Wasatch Formations. Direct infiltration of precipitation provides a minimal source of recharge over most of the area because the climate and surface features prohibit significant infiltration.

Early (pre-mine) data on water levels indicate that hydraulic gradients for the coal and clinker are steep near the outcrop with highest potentials in the clinker, suggesting that the clinker provides recharge to the coal. However, the rate of recharge from the clinker units to the coal is often limited by a relatively low-permeability, clay-rich zone that typically occurs at the contact between the clinker and the coal.

Infiltration of surface water in creek valleys is considered an important source of recharge to the underlying alluvium and the shallow bedrock aquifers. A USGS study of two ephemeral drainages in the southern part of the PRB indicated stream losses of between 0.43 and 1.44 acre-feet per mile from individual storm runoff events (Lenfest 1987) and these values were acknowledged to be underestimated. Recharge to shallow aquifers from stream valleys ranged from 3.56 to 26.5 acre-feet per mile for individual storm runoff events in the same study. Recent studies of the losses of surface water in several drainages of the PRB that receive CBM produced water during dry weather indicate that conveyance losses range from 64 percent to 100 percent of inflows (Babb 1998, Meyer 2000b, AHA 2001b).

Conveyance losses include both evapotranspiration and leakage into alluvium and bedrock that underlie the streams. Evapotranspiration varies seasonally, but probably accounts for less than 20 percent of the conveyance losses over the course of a year. A monthly water balance calculation for the Wild Horse Creek drainage found that evapotranspiration accounted for 18 percent of the conveyance loss associated with the surface discharge of CBM produced water within the drainage basin (Hydrologic Consultants Inc. 2001). Recharge of shallow aquifers through leakage from rivers or streams probably accounts for more than 80 percent of the conveyance loss.

Discharge of CBM produced water to surface drainages was assumed for this analysis to result in a 20 percent total conveyance loss, of which 82 percent

3

would be caused by infiltration and 18 percent would be a result of evapotranspiration. These values are considerably lower than were derived in some studies of surface water losses in several drainages of the PRB (Lenfest 1987, Babb 1998, Meyer 2000b, AHA 2001b) and represent a net recharge to shallow groundwater of just over 16 percent of the water produced. Higher values for conveyance loss would correspond to unsaturated stream channel conditions. Perennial flows likely would be associated with the surface discharge of CBM produced water and would create saturated stream channel conditions. Lower values for conveyance loss would apply to saturated conditions.

This analysis assumed that water discharged into infiltration impoundments would result in 85 percent of the total volume evaporating or infiltrating into the shallow groundwater system (28 percent evaporation, 57 percent infiltration). Fifteen percent of the total volume discharged into infiltration impoundments would resurface and contribute to surface flow. This estimate of infiltration was used in the analysis to ensure that the environmental effects that could result from substantial infiltration of produced water are considered in the groundwater model analysis.

This analysis also assumed produced water discharged to large containment impoundments that are constructed to allow negligible infiltration and minimal loss to soil moisture (10 percent) would not infiltrate into the shallow aquifer system. There would be no recharge to shallow groundwater from this water handling option.

Furthermore, the analysis assumed that all of the produced water used for land application disposal would be used consumptively. There would be no net recharge from this water handling option.

Injection of CBM produced water results in recharge to the zone of injection. Injection was assumed in this analysis to occur in zones deeper than the Fort Union coal zone. There would be no net recharge to the Wasatch sands or the coal zones within the Fort Union Formation from this water handling option.

Recharge to the Fort Union coal zone and higher units by infiltration of CBM produced water is summarized by sub-watershed for each alternative in Table 4-1. An estimated 15 to 33 percent of the CBM produced water would infiltrate the surface and recharge the coal zone aquifer under Alternative 1.

Hydraulic connection between the sands of the Wasatch Formation and the coals of the upper Fort Union Formation is limited because of the low permeability claystones that separate the two units. However, if the hydraulic head (water level) in the coal is naturally lower than in the overlying sands, then there is potential for leakage from the sands into the coal. Based on observation of water levels in nested monitoring wells, considerable leakage into developed coals is expected only where Wasatch sands occur within 100 feet above or below the coal zone. The rate of leakage typically would be extremely small, but can amount to a significant portion of the total recharge into the coal taken over a large area.

Table 4–1 Percentage of CBM Produced Water Recharging the Coal Zone Aquifer and Higher Units

	Alternative		
Sub-watershed	1 and 3	2A	2B
Upper Tongue River	33	39	28
Upper Powder River	22	40	29
Salt Creek	30	42	29
Crazy Woman Creek	15	43	28
Clear Creek	30	43	30
Middle Powder River	17	37	29
Little Powder River	17	34	21
Antelope Creek	30	28	24
Upper Cheyenne River	30	28	24
Upper Belle Fourche River	31	28	28
Range (all sub-watersheds)	15–33	28–43	21–30

Source: AHA and Greystone 2002

As sands in the Wasatch Formation tend to be discontinuous, the amount of leakage would also be limited by the areal extent of sands within 100 feet of the coal. Locally, the hydraulic connection between the coal zone and Wasatch sands may be enhanced if the integrity of the confining layer is compromised by water supply wells that are screened through both the coal zone and the overlying sands, by deteriorating well casings, or by poorly plugged oil and gas wells or exploratory drill holes. Leakage from the Wasatch sands into the coal zone also may be enhanced if water levels in the coal are lowered as a result of dewatering. A significant period (typically several years) would likely pass before noticeable drawdown (drop in water level) in the sands would be apparent because of the limited hydraulic communication between the coal zone and the overlying Wasatch sands.

Partial isolation of the sand aquifers that overlie the coal is indicated in the results of the BLM's groundwater monitoring of the Marquiss CBM project, which has the longest history of operation (since 1993). The BLM has monitored two sets of paired wells since the project began. In one set of wells, the MP–22C well is completed in the coal and MP–22S well is completed in the first overlying sand zone, 40 feet above the coal. A decline in the water level of more than 300 feet has been observed in the coal monitoring well, while a decline in the water level of 20 feet has been observed in the overlying sand aquifer after more than 9 years of monitoring (Figure 4–1). A lag time of about 4 years occurred before any measurable drawdown was seen in the well completed in the sandstone. A second pair of wells in the area (MP–2C and MP–2S) shows a similar trend.

The two pairs of monitoring wells in the Marquiss field are the only source of long-term monitoring data available for Wasatch sandstones in a CBM development area within the PRB that has been active for several years. The BLM has been active in setting up and monitoring paired wells in other areas of the PRB, but the history of data for these wells is relatively short. However, the data from these nested wells can be used to evaluate the vertical permeability and leakage rate through the 40-foot thick claystone unit that separates the coal from the sandstone in this area (AHA and Greystone 2002).

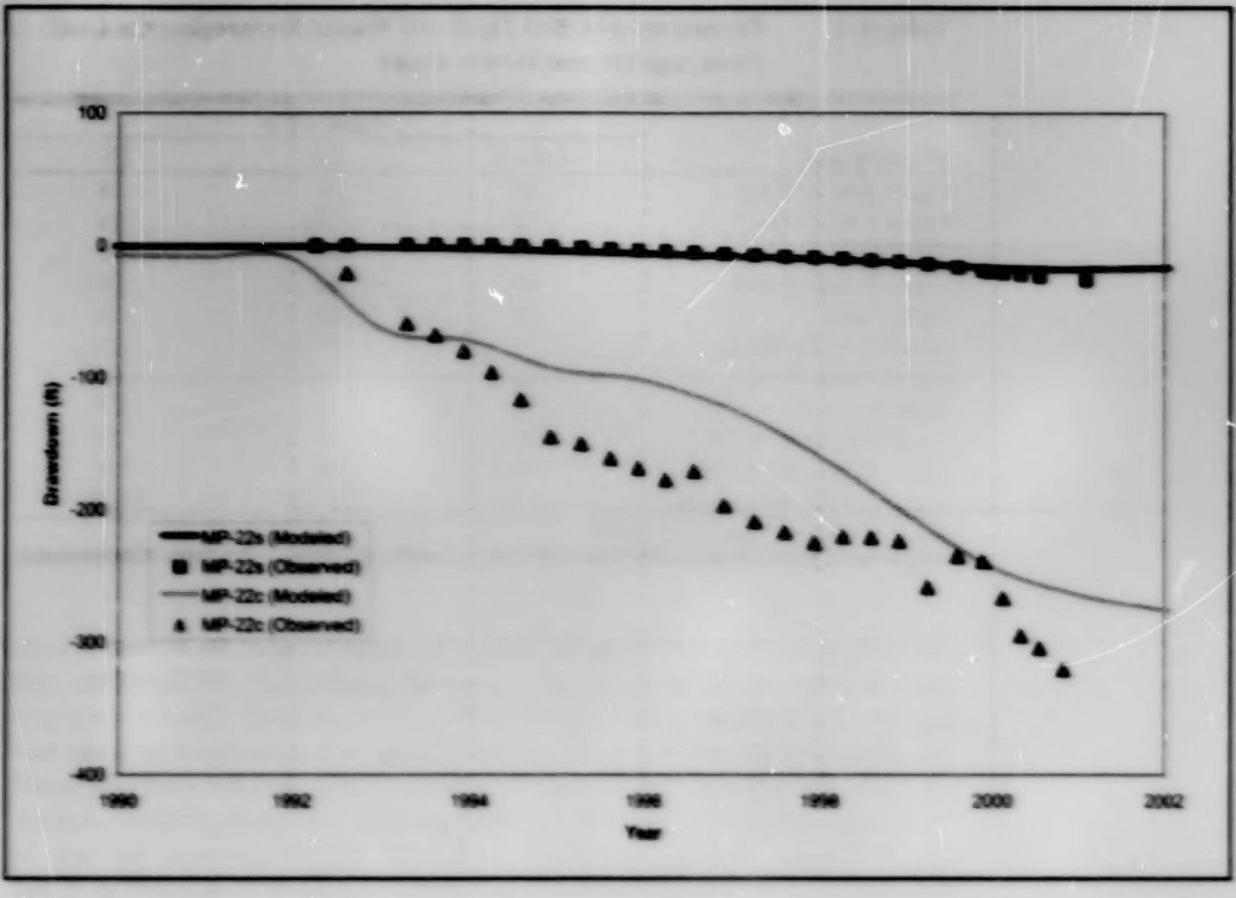


Figure 4–1 Modeled vs. Actual Drawdown Graphs for BLM MP–22 Monitoring Wells (West of Belle Ayr Mine South of Gillette)

Although the nature of the separation between the upper Fort Union coals and the overlying sandstones in the Wasatch Formation varies greatly over the PRB, the data from the Marquiss area demonstrate that a 40-foot thick claystone unit provides a significant hydraulic barrier but allows a small amount of leakage from the overlying sandstone into the pumped coal zone. This leakage is important when the recovery of water levels after CBM pumping ends is considered. Thicker sequences of claystone that separate the coal from the sandstone would be expected to provide even more effective separation because induced vertical gradients through the claystone unit would be less. The partial isolation of the sand aquifers that overlie the coal that has been documented by BLM monitoring is assumed in this analysis to apply to other areas of the PRB.

Through time, many clinker deposits have become saturated as a result of the infiltration of precipitation and snowmelt. Water may pond along the interface where clinker meets the less permeable transition zone between the clinker and the unburned coal. Springs may form at the base of the clinker deposits. Moyer Springs, located north of Gillette, is an example of this situation.

Before significant coal mining and development of CBM began, regional flow of groundwater in the eastern part of the PRB was generally to the northwest (downdip) toward potential discharge areas in the north-central part of the PRB. Coal wells near the Powder River exhibit flowing artesian conditions indicative of upward flow gradients. This indication of upward flow supports the potential for groundwater discharge along the northern part of the Powder River, although physical evidence, in the form of springs and sustained river base flow, is not readily apparent. Water balance calculations for the northern reach of the Powder River indicate that bedrock discharge to the alluvium is very low, in the range of 5 to 20 cfs, suggesting that most of the discharge is diffuse and may be consumed by evapotranspiration so that it does not appear as surface flow (AHA and Greystone 2002). A significant portion of deeper groundwater flow in the PRB probably discharges farther north, into the drainage basin for the Yellowstone River.

Groundwater Modeling Methodology

One tool used to predict impacts to the groundwater system under Alternative 1 was numerical groundwater flow modeling. Modeling was necessary because of the large extent of, variability in, and cumulative stresses imposed by mining and development of CBM on the Fort Union and Wasatch aquifer units. Effects from development of CBM have been evaluated in earlier EAs for the Marquiss, Lighthouse, North Gillette, and South Gillette areas (BLM 1992a, 1995b, 1995c, 1996a, and 1997a). A detailed modeling study was completed for the Little Thunder drainage basin in the southeastern part of the PRB (Wyoming Water Resources Center 1997). The eastern part of the PRB was modeled for the Wyodak EIS (BLM 1999d). The information from earlier studies was reviewed and incorporated wherever practical into the modeling for this analysis.

The computer model used to support the analysis of groundwater for this project is briefly described here. The complete technical description of this groundwater model is found in the Technical Report for the Powder River Basin Oil and Gas Project, Groundwater Modeling of Impacts Associated with Mining and Coalbed Methane Development in the Powder River Basin (AHA and Greystone 2002), on file at the CFO in Casper, Wyoming, and at the BFO in Buffalo, Wyoming. This report describes the specific hydrogeologic data used as the basis for the model. It also describes the numerical model and model assumptions in more detail.

Conceptual Regional Model

The regional model of groundwater flow for the PRB was based on the conceptual model that has its foundation in the geology and hydrogeology described in Chapter 3. The lateral continuity of the coal bearing units of the upper Fort Union Formation is considered sufficient such that they act as a regional aquifer system. Although individual coal seams may split and merge, there is sufficient hydraulic communication, on a regional scale, to allow movement of groundwater from areas of recharge predominantly at the higher topographic elevations along the eastern, western, and southern margins of the basin, toward the lower topographic elevation areas along the northern margin of the basin. The structure of the upper portion of the Fort Union Formation is reasonably well documented and can be used as a framework for the layers in the regional model. Recharge is primarily through infiltration of runoff in the extensive network of ephemeral drainages that characterize the surface topography of the PRB. This infiltration can be characterized as an overall areal recharge when considered in a regional perspective.

BEST COPY AVAILABLE

Groundwater flow within the Wasatch Formation is dominated by local rather than regional flow systems. The general lack of laterally extensive transmissive units and the dissection of the shallow portions of the formation by surface drainages, result in shorter, more localized flow paths from recharge to discharge areas. Much of the recharge that enters the Wasatch Formation probably remains in a relatively shallow groundwater system and eventually discharges in topographically lower areas in the form of transpiration, springs, or seeps. The alluvium within larger drainage channels conducts some of this shallow groundwater flow.

Over most of the PRB, the potentiometric pressure within the shallow Wasatch sandstones is higher than in the deeper Wasatch sandstones and the underlying Fort Union Formation coals. This generally downward hydraulic gradient induces a component of vertical groundwater flow so that some portion of the recharge to the Wasatch Formation may eventually leak into deeper regional flow systems. Low-permeability claystone and siltstone units retard the downward movement of groundwater and may locally divert flow laterally. On a regional scale, however, this slow component of downward flow provides most of the recharge to the Fort Union coal zone aquifer. Some recharge to the Fort Union coals occurs in coal subcrop areas through clinker zones. Although the clinker has a high capacity for infiltration, the low permeability of the contact zone between the clinker and the unburned coal usually limits the rate of recharge to the coal and may cause ponding in the clinker and springs to appear at the contact.

The regional groundwater system discharges to the topographically lower valleys in the PRB, primarily the lower reaches of the Powder, Little Powder, and Tongue Rivers in the northern portion of the PRB. The groundwater discharge is relatively small and diffuse, and is not readily discernable as stream baseflow. Flowing artesian wells along the Powder River Valley form a small component of this bedrock discharge. Some discharge also occurs to the Cheyenne and Belle Fourche River drainages, but tends to be from shallow local groundwater flow systems rather than deeper regional flow systems.

Model Construction

The hydrogeologic model code selected was the USGS Three Dimensional Finite Difference Modular Groundwater Flow Model, MODFLOW–96. This model code is widely accepted by regulatory agencies and currently is used by the BLM.

The regional model consists of 17 layers. The lowermost three layers (layers 15, 16, and 17) represent the lower members of the Fort Union Formation and the claystone aquitard that separates these members from the overlying coals in the upper portion of the Fort Union Formation. The coal-bearing units of the upper portion of the Fort Union Formation are represented by layers 8, 10, 12, and 14 in the model. The intervals between the coal-bearing units are represented by layers 9, 11, and 13. As the coal-bearing units split and merge in the PRB, the hydraulic properties assigned to the layers that represent both coal-bearing units and intervening units would change accordingly. The coal-bearing units transition into more highly permeable clinker in outcrop areas. Overlying the four coal-bearing units is a layer (layer 7) that represents claystones within the Wasatch Formation that act as a confining unit between the coal-bearing units and the discontinuous sandstones within the Wasatch Formation. Layers 1 through 6 represent the Wasatch Formation, consisting of alternating layers of discontinuous sandstone units and claystone and siltstone units. The discontinuous nature of the sandstones in the Wasatch Formation was modeled by assigning hydrologic parameters to these layers that are representative of mixed sandstone and claystone and siltstone units. The uppermost layer (layer 1) represents surface geologic units, including claystones, sandstones, and alluvial sediments within creek valleys.

Other geologic boundaries that were incorporated into the model include faults and lineaments where they are suspected of having a significant influence on groundwater flow regimes. Faults may act as impermeable (no-flow) boundaries or zones of flow restriction, and lineaments as zones of augmented hydraulic conductivity in the model.

The mining sequence was simulated for geographic locations where mining would occur as incremental impacts in 1-year stress periods from approximately 1975 (the earliest mining along the Wyodak outcrop, with the exception of the Wyodak mine located east of Gillette) to 2033 from reasonably foreseeable mine plans. Predictive simulations of impacts were modeled to 2200. Historical mining records and life-of-mine plan maps on file with the WDEQ in Cheyenne were used to develop historical mine sequences and to project the approximate future mining sequence. Although life-of-mine plans are dynamic and may change in future years, they provide a general projection of likely coal removal sequences and mine progression. Annual progress of the mine plans was superimposed on the grid as drains within the model, with the pits left open for 3 years, and then closed. Mining drains are set with drain elevations positioned just above the base of the mined coal seam. When mined areas are reclaimed, the drains are removed from the model so that water levels can recover.

Current production of CBM was simulated in the area using the historical operational data from the existing fields. Future development of CBM was simulated using the estimate of future development described in Chapter 2. Annual progress of development of CBM was simulated as drains within the appropriate model cells. These drains were set at an elevation of 16 feet above the top of the highest developed coal seam in the area. Historical CBM production sequences were simulated using data on water production available from WOGCC. Estimates of future production of CBM water assumed an average operational life of 7 years for each projected CBM well.

Steady-state model calibration was performed by matching to pre-mining water levels or, in a few cases, to the earliest available static water levels and to estimated bedrock discharge to alluvium in the lower reaches of the Powder River. This match was assumed to represent steady-state conditions. The model was calibrated in the transient state by matching model results against available historical data for water level monitoring and CBM well production. Sources of the data for water level monitoring used to calibrate the model include Daddow 1986, Lowry and Cummings 1966, Martin et al. 1988, USGS 1974, Hodson et al. 1973, the Gillette Area Groundwater Monitoring Organization [GAGMO] (Hydro-engineering 1996, 2000), individual mine data, and BLM. Data for CBM well production came from the WOGCC database and were reviewed by BLM.

The following information used in the model analysis is described in Chapter 2. New CBM wells are projected by year and sub-watershed. The percentage of CBM produced water that would be handled using discharge to surface drainages, infiltration, containment, land application, and injection is projected for each sub-watershed.

The model used data for the production of water from WOGCC as the source for input of drains during the period from 1988 to March 2001. A total of 6,098 wells show some production of water during this period. The life span for production was assumed to be 7 years from the start of production. For the period from March 2001 to March 2002, 3,677 permitted wells were assumed to enter production. These wells were assigned a 7-year life span. It was assumed that future wells would be drilled over a 10-year period from March 2002 through March 2012 and that each would have a 7-year life span, as described in Chapter 2. A total of 39,367 new wells were input into the model as drain nodes with appropriate time schedules and conductance. The producing intervals of the wells were distributed among the four coal-bearing units (layers of the model) based on existing production or the thickness and depths of the coals in any area. More than one coal interval would be produced in many areas and is reflected in the model where more than one well per well pad is projected.

The effects of the various water handling methods were simulated in the model by applying additional recharge to the portion of each sub-watershed affected by CBM development on a year-by-year basis during the production period. The amount of recharge was based on modeled production of water, the projected percentage of water handled by the various methods, and the projected infiltration associated with each method of water handling. The additional recharge was converted to a year-by-year infiltration rate based on the area of CBM development in each sub-watershed.

CBM wells in Montana were not included within the regional model for the following reasons. First, the regional model used to project impacts from CBM development in Wyoming requires some input parameters that could not be estimated for the proposed CBM wells in Montana. Detailed information on methods of water handling that was not available would have been needed to account for infiltration and recharge in the model to include projected CBM wells in Montana within the regional groundwater model. In addition, the regional model was designed to provide a conservative estimate of the upper limits of water production in Wyoming. If CBM wells in Montana had been added to the regional model, the effect would have been to suppress water production from some CBM wells in Wyoming. The exclusion of CBM wells in Montana from the regional model likely resulted in the underestimation of the extent of impacts to the potentiometric surface in some areas near the Wyoming-Montana state line.

Limitations of the Model

Numerical groundwater models can be particularly useful tools for refining the conceptual model of the groundwater flow systems within a regional basin. However, any regional model of this size will involve limitations based on the size of the grid nodes and the simplification of a complex hydrogeologic system necessary for creating the model. The primary purpose of modeling a hydrologic system on a regional, basin-wide scale is to calculate the mass water balance so that long-term gain or loss can be evaluated and to compare the relative effects of various alternatives. The regional model is an adequate tool for a comprehensive assessment of the effects of CBM development. The results should, however, be viewed in perspective with the scale, and a sub-regional or local area model should be used to help evaluate impacts on a smaller scale.

The regional model was constructed using averaged and smoothed values so that localized conditions are typically not well refined. The size of each node in the model is ½ mile by ½ mile, so infiltration impoundments, small streams and rivers, and other smaller features cannot be represented exactly. Rather, smaller features are represented by the application of boundary conditions over the entire grid node. For example, infiltration of water from an impoundment is applied over an entire cell as a very small recharge rate. This assumption is less accurate for individual features, but becomes more representative of actual conditions as the density of features within a grid node increases.

Smaller-scale models can be used to provide more definition of the interconnectivity of the hydrogeologic units. Two sub-area models, which are developed at a much smaller scale, complement the regional model and were used to demonstrate specific aspects of CBM development in the PRB. The Caballo Creek sub-area model was used to match transient water data in an area with a relatively long history of CBM development. This modeling allowed an evaluation of hydrologic parameters for confining zones that have a major influence on projections of shallow aquifer drawdown and coal recovery after CBM pumping ceases. The LX-Bar sub-area model was developed specifically to examine the potential influences of infiltration from impoundments on shallow groundwater levels in the Wasatch sands and adjacent creek flows in an area where surface discharge would probably be limited in light of water quality considerations.

In the regional model, the Fort Union coal units are reasonably well defined, but the Wasatch units lack adequate definition. The Wasatch Formation is highly variable throughout the basin but, lacking sufficient geologic data, the Wasatch Formation was arbitrarily divided into six layers in the model. No impacts for the Wasatch Formation predicted by the model are included in this impact analysis.

The construction and calibration of the regional model was limited by a lack of data from observation wells and on production and geology for the Wasatch Formation away from areas of development. The results of the model are potentially skewed by the data that are available. Results of the model from areas of the basin that lack adequate calibration data should be considered only as a general indicator of potential effects. The model should be updated and refined as new data become available.

In the regional model, CBM wells were simulated using drain boundary nodes. Any node could encompass one to four actual CBM wells per layer and up to 16 wells per model column. The number of CBM wells represented per drain was accounted for by varying the drain conductance. Using a drain boundary applied over the entire node to represent a CBM well, which is more or less a single point within the node, will tend to over-predict the water production of a single well during the early stages of production. However, as well density increases within a node, the drain boundary becomes a better representation of CBM production.

11

Another model limitation stems from the way the MODFLOW code handles the case where the water level in a cell falls below the base of the cell because of depressurization imposed by pumping or drainage stresses. When a cell becomes dry, the MODFLOW code treats it as inactive, so that water cannot move through that cell and any boundary conditions effectively will be removed from the model. MODFLOW allows cells to resaturate when water levels recover as a result of removing the stresses through a rewetting package. However, during the period that dry cells occur, they can affect the horizontal and vertical movement of water throughout the simulated aquifer system. In the regional model, cells became dry because of simulated mining and CBM development. The MODFLOW rewetting package was used to mitigate the impacts of the dry cells on results. The rewetting package also has limitations, particularly with regard to solution convergence. For the transient regional model, the convergence criteria were relaxed in some stress periods to allow convergence for the transient regional model. However, the water balance checks in the model indicated that a reasonable solution was reached.

Alternative 1

The following discussion outlines the projected effects on water yield and aquifer characteristics or conditions, including groundwater quantity, quality, and use.

Water Yield (CBM Produced Water)

Table 2–8 shows the projected quantity of water that would be removed during CBM development from 2002 through 2017, summarized by sub-watershed. Within the Project Area, water production is projected to peak during 2006 at a rate of 386,336 acre-feet per year.

This CBM produced water would consist primarily of groundwater pumped from storage within the developed coals and water that leaked from nearby sand layers into the coals as a result of coal depressurization. Over the life of a CBM well, most of the produced water likely would come from leakage into the coal from sand layers above and below the coal zone. Groundwater that can be recovered from the coal by pumping would be removed early in the life of a CBM well. All of the recoverable groundwater stored in the coal zone within the Project Area could feasibly be produced by the end of 2009, using the projected water production in Table 2–8 and the estimate of recoverable groundwater in Table 3–5. However, the vast majority of recoverable groundwater in the PRB is contained in the sandstones of the Fort Union and Wasatch Formations. The projected CBM water production from 2002 to 2017, about 3 million acre-feet (Table 2–8), is much less than 1 percent of the recoverable groundwater (almost 750 million acre-feet) in these formations (Table 3–5). Depending on the water handling practices used within each sub-watershed under Alternative 1, an estimated 15 to 33 percent of the pumped water would be recharged to the groundwater system as a result of infiltration along creeks and below impoundments (Table 4–1).

An example illustrates this concept and explains production declines that are typically seen in the PRB. The example considers a 50-foot thick coal seam at a depth of 1,000 feet that is bounded above and below by 40-foot thick claystones that separate the coal from overlying and underlying sandstone units. It also as-

12

BEST COPY AVAILABLE

sumes that development of CBM is occurring on an 80-acre well spacing pattern and depressurization of the coal causes an average potentiometric head drop of 500 feet.

If the coal is not dewatered (water is removed from confined storage only by depressurization), then the contribution of coal to well water production depends on the head drop and the confined storativity. Using a typical storativity for the coal of about 5×10^{-6} ft^{-1}, the contribution to confined storage from the coal would be about 2 acre-feet for every 100 feet of head drop or 10 acre-feet in this example. Additional water in unconfined storage would be released to the well if the coal were completely dewatered. The unconfined storage in the coal depends on the thickness of the coal and the specific yield. Assuming a specific yield for the coal of 0.4 percent (Table 3–5), the amount of (unconfined) storage in the coal within the 80-acre-foot area of one production well would be 16 acre-feet. The confined storage contribution therefore becomes comparable with contribution to unconfined storage in the deeper parts of the basin where head drops of between 500 to 1,000 feet might be encountered. The total volume of coal storage (from confined and unconfined storage) of 26 acre-feet (about 8.5 million gallons) is equivalent to a well pumping at 10 gpm for 1.6 years.

Groundwater stored in the coal would be removed concurrently with leakage into the coal from above and below. Depending on the rate of leakage, the coal would not necessarily become dewatered in the short time frames noted. The contribution from leakage would increase over the life of a well as water stored in the coal is removed. Leakage rates under large induced vertical gradients can be significant. For this example, a 500-foot head drop would result in a vertical hydraulic gradient across the claystones of 12.5. Assuming very low vertical hydraulic conductivities for the claystone confining units, 6×10^{-11} ft/sec (derived from the Marquiss field data) results in a vertical leakage over the 80-acre area of 1.2 gpm from both above and below (for a total of 2.4 gpm). Higher head drops, higher vertical hydraulic conductivities, or thinner claystone units would lead to higher leakage rates. The leakage rates for this example are typical of the pumping rates for CBM wells during the latter portions of their productive life.

The example illustrates that after about the first 2 years of pumping, most of the water produced by a CBM well likely would be coming from leakage. The higher storativity and specific yields in the sandstones result in relatively less observable drawdown in these units compared with the coal (as actually observed in the nested monitoring wells in the Marquiss area), while still providing a large source of water for leakage into the coal.

Aquifer Characteristics

The removal of water from the coal seam is unlikely to have any measurable effects on the physical characteristics of the aquifer and its ability to store or transport water. Subsidence is discussed under the section on Geologic Hazards.

Aquifer Conditions

Removal of water from the coal seam and its subsequent disposal likely would have the following effects on conditions within affected aquifers at various times during or after development of CBM.

Alluvial Aquifers

Depending on the water handling practices used within each sub-watershed, an estimated 80 to 95 percent of the groundwater produced from CBM operations would be released to surface drainages or impoundments. A portion of the released water would recharge the alluvium. Several studies of water flow losses in creeks during dry weather periods show that a considerable portion of the discharged water infiltrates the alluvium within a few miles of the surface discharge outfall.

Water levels in alluvium likely would increase from discharges of CBM produced water. In areas with near-surface water tables, the increase in water level may be exhibited as standing water in areas not previously displaying this condition or as wetland development, unless the number of CBM wells releasing produced groundwater to surface drainages or impoundments is carefully controlled.

Ongoing studies conducted by BLM document effects and trends associated with the infiltration of CBM produced water into alluvial deposits. BLM studies in the following areas are described below: Brown Reservoir; Bone Pile Creek; Burger Draw; and Caballo Creek.

Discharge of CBM produced water into a shallow 6-acre reservoir (Brown Reservoir in T44N R76W) over a period of almost one year produced nearly a 10-foot rise in the alluvial groundwater level immediately adjacent to the reservoir within five months of the onset of discharge (Day 2000). Where infiltration impoundments are used as a water handling method, a rapid rise in alluvial groundwater levels could occur in the immediate vicinity of the impoundments within a few months of the onset of discharge. Water levels could return to pre-existing conditions within a few months after discharge ends, based on monitoring results in the Brown Reservoir area. No increase in water levels within alluvial deposits near stream channels located downstream of the impoundment could be documented (Day 2000).

The rise in water levels within alluvial deposits likely could be confined to the immediate area surrounding the infiltration impoundment, based on monitoring results in the Brown Reservoir area. A rise in water level of up to 10 feet has been documented at this reservoir; however, changes in water levels could be greater or lesser in other areas. The rise in water level would be constrained by the unsaturated thickness of the alluvial aquifer near an infiltration impoundment. Throughout the PRB, alluvial aquifers typically are thin (30 feet or less). In places, alluvial aquifers may have an unsaturated thickness of 30 feet, or may be saturated to within 5 to 15 feet of the land surface (Slagle et al. 1985, Lenfest 1987, Lowry and Rankl 1987, Ringen and Daddow 1990).

The rise in water level that could be expected within the alluvial deposits also could be constrained by the likelihood that lateral flows would occur, limiting the rise in water level. Slagle et al. (1985), in describing the hydrology of alluvium within the northern portion of the PRB, indicate that once water reaching the saturated zone raises the water table in the alluvium to above-normal levels, lateral flows would be induced, resulting in groundwater discharge to the nearby stream. For the purpose of this analysis, an estimated 15 percent of the water discharged to infiltration impoundments is assumed to flow laterally and discharge to surface drainages.

The results of monitoring in the Bone Pile Creek and Burger Draw areas indicate that CBM produced water infiltrating the alluvium is continuing to move downward and recharge the shallow Wasatch sand aquifer, even at depths as great as 100 feet below the alluvium. Shallow bedrock monitoring wells located close to areas where CBM produced water is discharging into creeks or impoundments show increases in water levels, indicating this recharge is occurring. Data also indicate that CBM produced water is not completely saturating the alluvial system. Declining water levels in the alluvium follow the recent trends in precipitation and production of CBM water for the Bone Pile Creek area. Monitoring in the Burger Draw area documents a 6-foot rise in alluvial water levels since discharges of CBM water began in this area in early 2002.

Studies of streamflow in Caballo Creek, below its confluence with Bone Pile Creek, indicate that no significant increase in streamflow can be measured since the onset of CBM production. A lack of increased base flow downstream of locations where CBM produced water has been discharging indicates that evapotranspiration from the alluvium and leakage into shallow Wasatch sand units may consume most of the CBM produced water discharged in the Caballo Creek drainage.

In other areas of the PRB, changes in water levels within the alluvium where CBM produced water is infiltrating the land surface would be expected to exhibit similar trends. Increases in water levels in the alluvium likely would closely follow increases in the discharge and infiltration of CBM produced water. Declining production of CBM water likely would result in declining water levels in the alluvium. Variations in local climate or precipitation in an area could affect water levels in the alluvium.

The City of Gillette currently pumps the alluvium of Donkey Creek within the community to maintain lower water levels. The city's pumping rate could have to increase to maintain current water levels during continued CBM field development.

Fort Union Coal Aquifer

Drawdown

Under Alternative 1, the maximum drawdown the model projects in the coal zone of the upper portion of the Fort Union Formation from development of CBM in the coal-bearing units would occur during the period from 2006 to 2009, depending on location and the coal-bearing unit. The modeled drawdowns for the four coal-bearing intervals in the model (layers 8, 10, 12, and 14) for the years 2006, 2009, 2012, and 2018 are shown in Figures 4–2 through 4–17. Because coal mining and CBM operations are dynamic, the maximum areal extent of drawdown may change over time and may increase in some areas of the PRB while it recovers in others. The maximum drawdown in any sub-watershed generally coincides with or closely follows the period of peak water production in the watershed (Table 2–8).

15

Projections of maximum drawdown and the extent of drawdown are based on the projected locations of CBM development. Actual locations and density of drilling may result in shifts of drawdown contours from the projections shown in Figures 4–2 through 4–17.

Maximum projected drawdowns would occur in the centers of CBM development. Within the northern portion of the Project Area, production of CBM would occur from two or more coal-bearing units. Drawdown would depend on the depth of the target coal below the surface. In deep areas of the basin, such as the central and northwestern portions, maximum drawdowns projected by the model would exceed 800 feet. In shallow areas of the basin, such as the southeastern portion, modeled drawdowns would be 200 to 400 feet over most of the active CBM well fields.

The locations of calibration monitoring wells are shown on Figure 4–18. Graphs of water level drawdown that show modeled versus actual drawdown over time for selected BLM monitoring wells in the Project Area are shown in Figures 4–1, 4–19, 4–20, and 4–21. Generally, the graphs indicate reasonable agreement between modeled and actual drawdown over time, although the Prairie Dog monitoring well shows considerably more drawdown than the model prediction. The regional nature of the model tends to smooth and average predicted drawdown (AHA and Greystone 2002). The graphs show that the changes in water level for the coal aquifer that would be induced by CBM development tend to be rapid.

Initial hydraulic head in the coal, as measured by the water level in a well completed in the coal, may be several hundred feet above the top of the coal. This initial hydraulic head is particularly true in the deep portions of the PRB, where the depth to the coal may exceed 1,300 feet. Removal of water from the coal in these areas during CBM development could result in drawdown of the hydraulic head to the top of the coal at the location of the pumping wells. For reference, where the depth to the coal is 1,200 feet and the depth to water in a well that taps the coal is 400 feet, an initial hydraulic head of 800 feet would exist. Even though the thickness of the coal itself may be only 100 feet, maximum drawdown in this example could be as much as 800 feet.

Recovery

Recovery of water levels in the coal would become apparent after water production started to decline. Water production starts to decline in different years for various sub-watersheds (Table 2–8). Based on the projected developmentof wells, all production is expected to end by about 2018. Recharge to the coal comes primarily from the redistribution of stored water in the surrounding coal and continued slow leakage from overlying and underlying sand aquifers in the Wasatch and Fort Union Formations.

BLANK PAGE

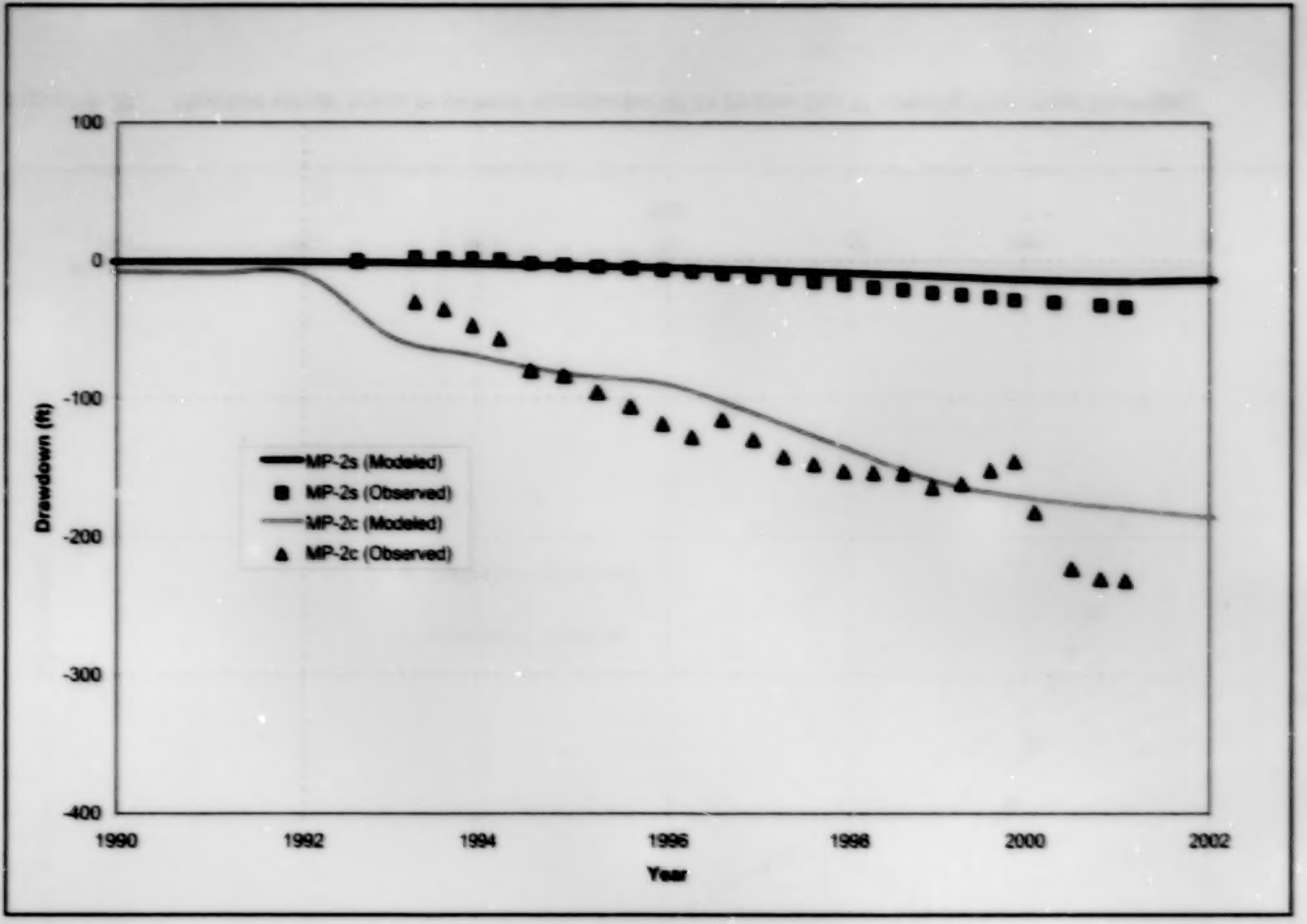


Figure 4–19 **Modeled vs. Actual Drawdown Graphs for BLM MP-2 Monitoring Wells (West of Belle Ayr Mine South of Gillette)**

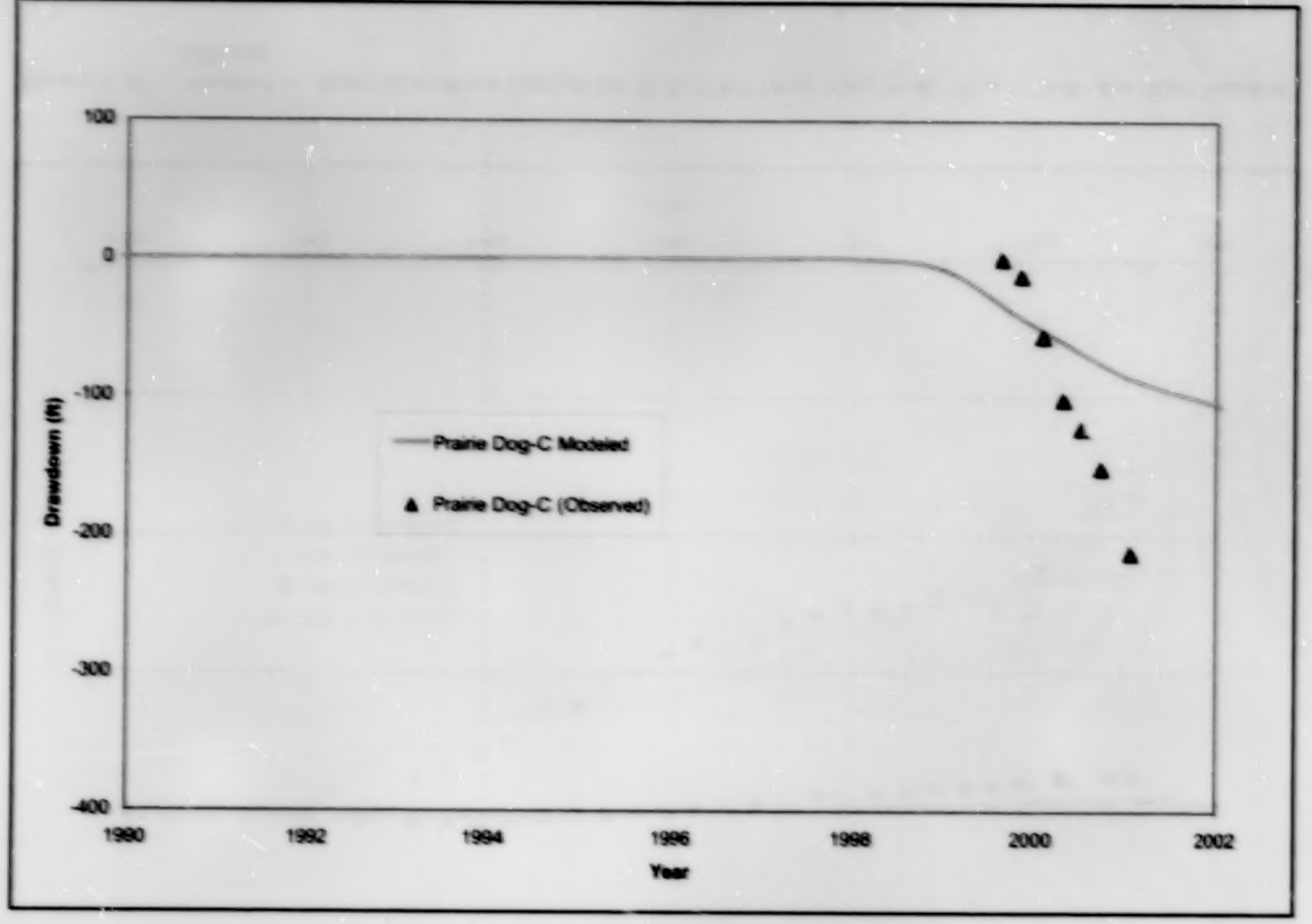


Figure 4–20 **Modeled versus Actual Drawdown Graphs for BLM Prairie Dog Monitoring Well (Near Sheridan)**

BEST COPY AVAILABLE

18

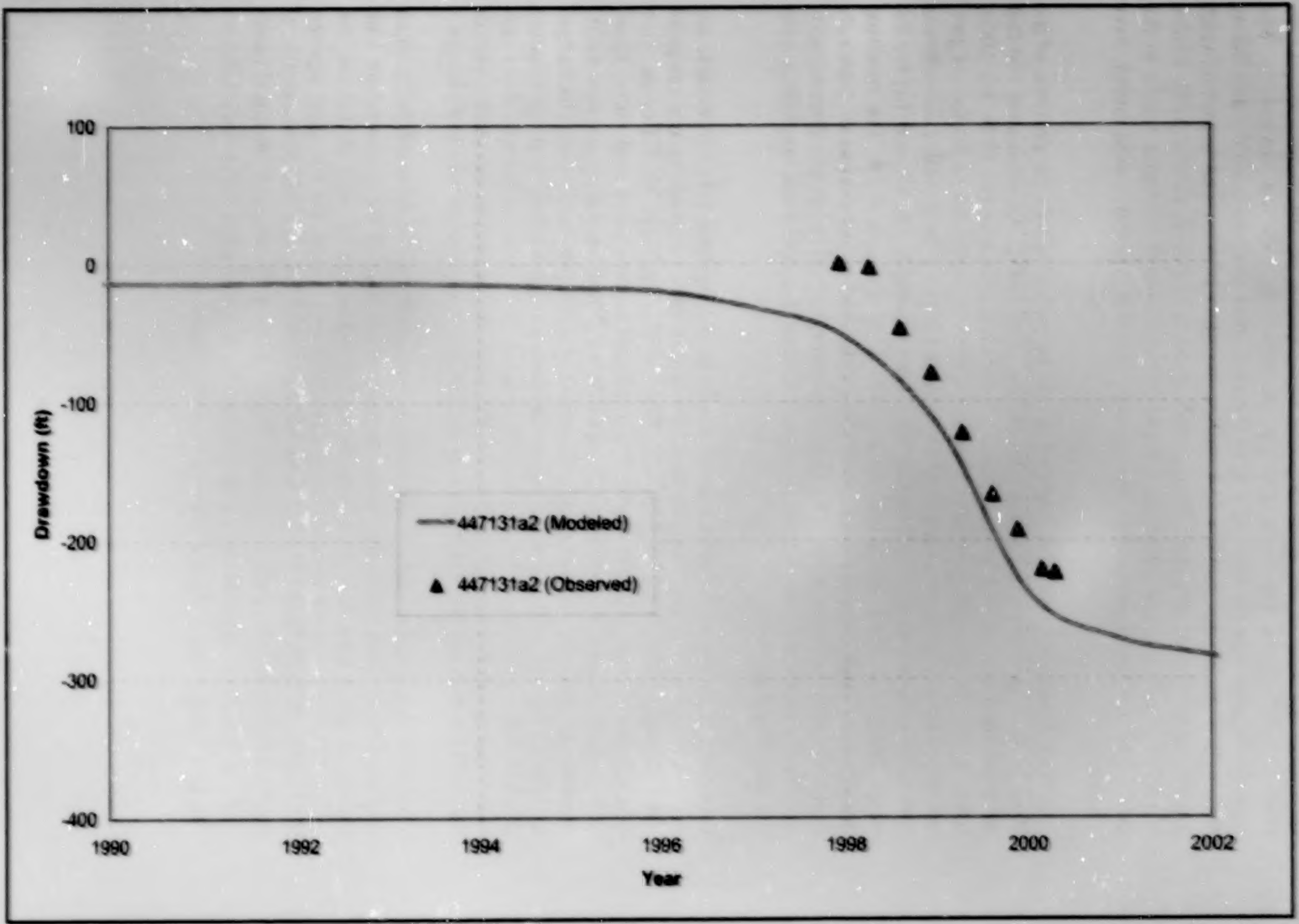


Figure 4–21 Modeled vs. Actual Drawdown Graphs for BLM 447131 Monitoring Well (Southeastern Powder River Basin)

BEST COPY AVAILABLE

19

Initially, recovery would be primarily a result of redistribution of groundwater stored in the aquifer. When the stresses of pumping are removed, the groundwater in storage outside the areas of CBM development would resaturate and repressurize the areas that were partially depressurized during operations. The amount of groundwater storage within the coals and sand units above and below the coals is enormous. Almost 750 million acre-feet of recoverable groundwater are stored within the Wasatch-Tongue River sands and coals (Table 3–5). Redistribution is projected to result in a rapid initial recovery of water levels in the coal. The model projects that this initial recovery period would occur over 25 years.

By 2030, drawdowns of 50 to 200 feet would be typical within the portions of the Project Area that have undergone development of CBM. An estimated 100 feet of drawdown would still exist in most of the coal seams in the PRB. By 2060, water levels in the coal generally would recover to within 10 to 50 feet of pre-operation levels, except in localized areas of the basin. The modeled drawdowns for the four coal-bearing intervals in the model (layers 8, 10, 12, and 14) for the years 2030 and 2060 are shown in Figures 4–22 through 4–29. The modeled drawdown distribution for year 2030 shows the end of the period of relatively rapid recovery in water level. The rate of recovery would then slow dramatically, eventually recovering to within 20 feet or less of pre-operation conditions over the next hundred years.

Complete recovery of the water level would be a long-term process because actual recharge to the coal aquifer would need to replace groundwater removed from storage during CBM operations. Most of this recharge would come from leakage from overlying and underlying sand and undeveloped coal units. These units would, in turn, be recharged from surface infiltration. Recharge rates would increase temporarily as a result of infiltration of CBM produced water discharged to impoundments and streams. However, based on modeling and information from nested wells, it would take tens of years before these influences from surface recharge would appear in the coal. Recharge to the coal in the central part of the PRB through surface infiltration at the outcrop areas would take even longer.

Coal mining along the eastern and northwestern subcrop would result in minimal recharge to the coal while the mines are active because of the groundwater sink caused by pit dewatering. As mines are reclaimed and eventually shut down, the backfilled areas would become long-term recharge zones for the coal aquifer. Infiltration through backfill areas may be substantial because the permeability of the backfill materials tends to be much higher than in the original unmined materials. In addition, most of the creeks would be diverted over these backfilled areas, providing an important source of recharge water.

Wasatch Sand Aquifer

Drawdown

Drawdown within the shallow and deep sands of the Wasatch Formation cannot be accurately projected by the regional model because of the variability of the sand units and the general lack of data available to calibrate the model layers that represent the Wasatch Formation. A detailed evaluation of the Caballo Creek area was performed because this area has a long history of CBM development and because long-term monitoring data are available from Wasatch sands close to the developed coal seams. A more detailed sub-area model was constructed for this area. The monitoring data allowed a more definitive calibration of the sub-model, and accordingly, the projections from the sub-model are likely to be more reliable. Figure 4–30 shows the modeled versus actual drawdown over time in the Caballo Creek area. Projections are shown for the coal and the deeper Wasatch sands, 40 to 50 feet above the developed coal. Maximum drawdown of the deep Wasatch sands is projected to reach about 60 feet in year 2010 (Figure 4–30).

Drawdown effects in deep Wasatch sands can be estimated by extrapolating the results from the Caballo Creek sub-area model. Over the PRB in general, the drawdown effects in the overlying Wasatch sand aquifers are likely to be much less than in the coal aquifer, but may be noticeable for deep sand units that occur within 100 feet of a developed coal. Based on the detailed model of Caballo Creek and existing monitoring data in the Marquiss area, drawdowns in deep sands that occur within 100 feet of developed coals may be between 5 to 10 percent of the projected drawdowns in the coal.

Drawdowns in the deep Wasatch sands would tend to occur several years after drawdown in the coal. The maximum modeled drawdown in the coal in the Caballo Creek model would occur about 6 years earlier than the maximum modeled drawdown in the deep Wasatch sands (Figure 4–30). Drawdown in the shallow Wasatch sands is expected to occur only near mines and areas where the target coal seam for CBM development is nearer the surface.

Recharge

Some of the groundwater released to surface drainages or impoundments would recharge shallow bedrock (Wasatch Formation). A portion of the water released would recharge the alluvium. In turn, the alluvium along many of the creek valleys would recharge the underlying Wasatch sands. The nature of recharge in any area is directly related to the permeability of the surface exposures of the Wasatch Formation under creeks and ponds.

Recharge to the Fort Union coal zone and higher units by infiltration of CBM produced water is summarized by sub-watershed for each alternative (Table 4–1). An estimated 15 to 33 percent of the CBM produced water would infiltrate the surface and recharge the coal zone aquifer under Alternative 1.

21

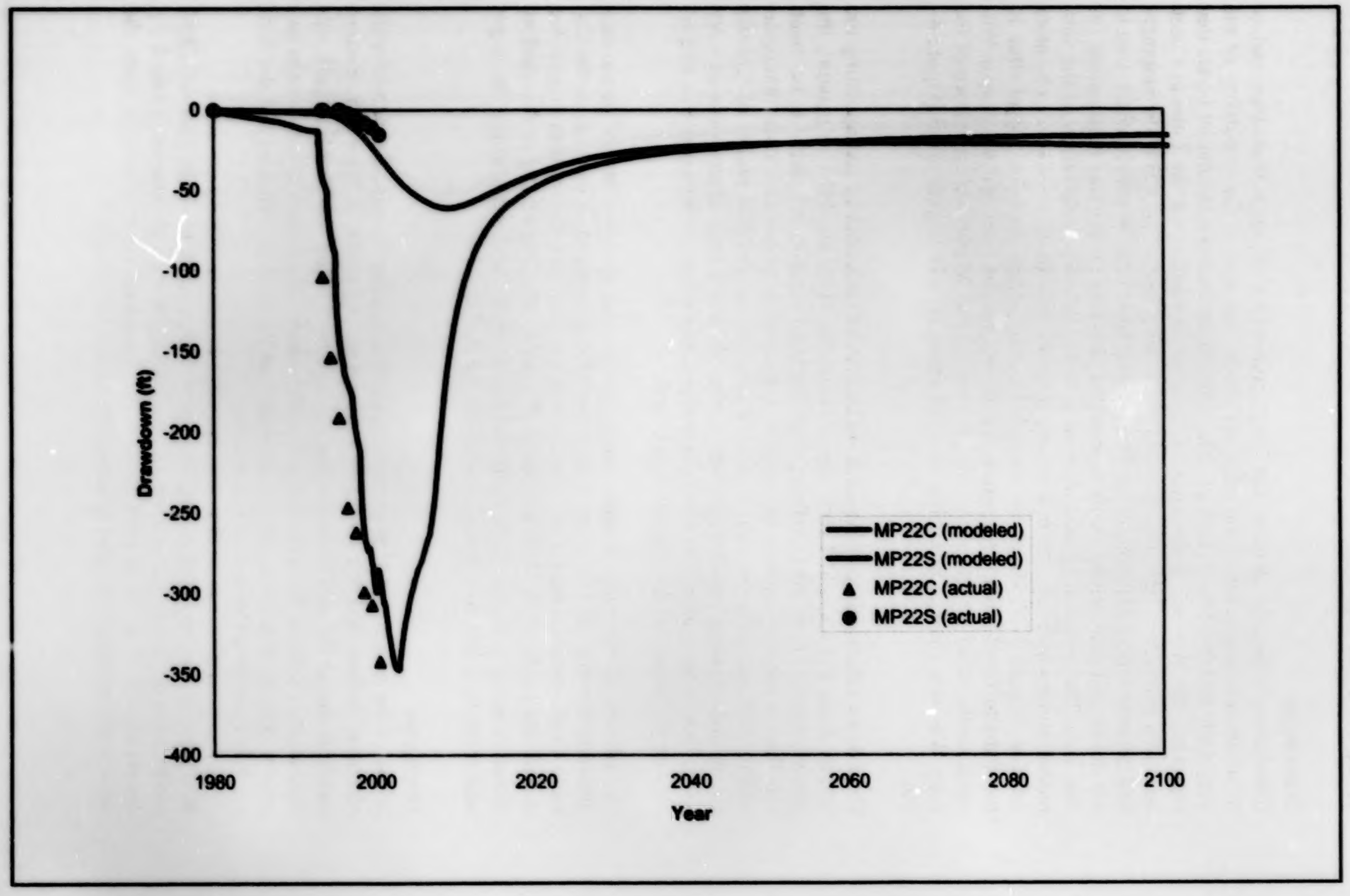


Figure 4–30 Modeled and Actual Hydrographs of Groundwater Levels in the Caballo Creek Area near Gillette

BEST COPY AVAILABLE

22

BLANK PAGE

The water levels in shallow Wasatch sands would increase because of infiltration of CBM produced water discharged to creeks and impoundments in some areas of the basin. Shallow bedrock monitoring wells located close to areas where CBM produced water is discharging into creeks or impoundments have shown water level increases, indicating that this recharge is occurring. The changes in water level for shallow Wasatch aquifers from this recharge effect could not be adequately assessed by the regional model but were evaluated by examining the area of affected alluvial drainages and the probable range of vertical infiltration rates into the Wasatch Formation below the creeks and ponds in a sub-area model covering the LX Bar watershed (AHA and Greystone 2002).

Based on the detailed model completed for the LX Bar sub-watershed, water levels in the shallow Wasatch sands in the immediate vicinity of infiltration impoundments may experience increases of as much as 50 feet. Water levels in shallow sands at locations more than a few hundred feet from impoundments or creek discharge points would tend to increase slowly, with a projected increase of 10 feet (AHA and Greystone 2002).

The regional model included the recharge volumes from CBM discharge to ponds and creeks. The total discharge from CBM operations was obtained from the model output for each of the sub-watersheds. This projected water production would be managed according to the options for water handling identified for each sub-watershed under Alternative 1 (Table 2–9). The projected net recharge was calculated using the percentage of the produced water handled by each method and the projected loss through infiltration. This infiltration has been characterized as an areal recharge, considering the scale and limited detail in the regional model.

The calculated net recharge volume, on a year-by-year basis, was divided by the area of projected development of CBM within each sub-watershed to obtain an equivalent recharge rate for the area, in inches per year. This additional recharge was then input into the model for the area of development of CBM within each sub-watershed during the period when CBM operations are expected to be active.

Recovery

Recovery in the deep Wasatch sands would tend to occur after water levels in the coal recovered substantially and induced leakage from the deep Wasatch sands into the coal became minimal. The projected recovery of water levels in the deep Wasatch sands after the end of development of CBM would be slow until water levels recover in the coal because the sands would continue to recharge the coal even after development of CBM ceases.

After the water levels in the coals recover substantially and the induced leakage from the deep sands into the coals becomes minimal, the Caballo Creek sub-area model projects that water levels would recover to within 25 feet of pre-operation levels over 20 years after CBM development ends in the area. Throughout the Project Area, recovery within the deep Wasatch sands generally would show trends similar to the Caballo Creek area, likely experiencing recovery of more than 50 percent by 2030. Water levels would eventually recover to within less than 20 feet of pre-operation levels over the next hundred years (Figure 4–30).

23

Groundwater Use

Water Wells

Impacts to individual water wells completed within the coal, and in sands above the coal, would depend on proximity to CBM production wells, depth and completion interval of the water well, and the yield required to maintain the well as a usable source. Drawdown of water levels in coal aquifers caused by development of CBM may affect individual well users by reducing well yield. Refer also to the discussion of Methane Emissions presented below.

Under Alternative 1, the model projects more than 800 feet of coal aquifer drawdown near the centers of active development of CBM. The maximum available drawdown (the hydraulic pressure head) in the coal aquifer in the affected areas ranges from 300 to 1,400 feet. Most individual water supply wells in the coal seam do not exceed 600 feet in depth and have up to 300 feet of available drawdown. Well pumps typically are set between 50 and 200 feet below the static water level in the well. Impacts in terms of well yield or availability are likely to be an issue only if the drawdown exceeds 20 to 30 percent of available drawdown at any location. This area would tend to coincide with the area of drawdown in excess of approximately 100 feet. The decreased head the well pump operates against may cause the pump discharge to decrease. However, yield may be restored by installing a larger pump if sufficient available drawdown remains in the well. In cases where the drawdown causes the water level in a well to drop below the intake, the pump may have to be lowered in the well.

Changes in water levels in wells are not expected to be as significant in the aquifers above or below the coal because it is confined both above and below by low-permeability claystone layers over most of the PRB. Examination of drilling and geophysical logs from CBM wells shows that the coal seams are separated from sands in the overlying Wasatch Formation by a relatively continuous, low-permeability claystone and siltstone confining layer that ranges in thickness from 11 to 363 feet. In most cases, the claystone confining unit is at least 30 feet thick. The large variation in thickness is mostly a function of whether any significant sands exist in the lower part of the Wasatch Formation at a given location. This claystone unit restricts hydraulic communication between the coal and the overlying Wasatch sands. A significant period (typically several years) likely would pass before drawdown effects caused by pumping groundwater from the coal are apparent in the overlying Wasatch sands. Although as noted in Chapter 3, the integrity of the confining layer may be compromised locally by water supply wells that are screened through both the coal and the overlying sands, by deteriorating well casings, or by poorly plugged oil and gas wells or exploratory drill holes, isolated local influences would not affect regional results.

Drawdown in the Wasatch sands may affect users of water from the Wasatch aquifer. The water well agreement would protect landowners if impacts were to occur on federal mineral ownership lands and non-federal lands where the agreement is in place.

The model also indicates that the sand units in the lower members of the Fort Union Formation may experience declines in water levels of up to 50 feet where

BEST COPY AVAILABLE

24

intensive CBM production occurs in the overlying Fort Union Formation coals. This drawdown is unlikely to noticeably affect use of these aquifer units for water supply. Refer to the section on mitigation measures for water wells that are affected individually. A standard agreement has been developed by CBM operators to monitor and mitigate impacts to owners of individual water wells that are caused by CBM operations. A copy of this water well agreement format is contained in Appendix G. Wyoming Statute 41-3-933 specifically states that groundwater levels and artesian pressures in water wells are not guaranteed.

Artesian flow has been reported in wells located near the Powder River, where the hydraulic head from the deep coal aquifer extends to the surface. Groundwater has been discharging in this area, in part, to artesian wells. A reduction in hydraulic head within the coal aquifer (projected to occur during development of CBM under Alternative 1) likely would reduce or eliminate artesian flow in water wells. Artesian flow in wells likely would not recover until hydraulic head in the coal aquifer recovers sufficiently after development of CBM.

The recovery of the coal zone aquifer projected by the model is based on the assumption that significant infiltration from the surface would extend downward and reach the Fort Union Formation. The recovery time frame and the likelihood that complete recovery would occur are not certain, based on currently available data. Recovery of the hydrostatic head in the coal aquifer after groundwater is extracted by CBM operations may not ever be complete or may be a slow process if infiltration and leakage from the overlying Wasatch Formation are inhibited or stopped by shale confining layers above the coal zone at some locations. The period of recovery could be long, longer than a lifetime, or complete recovery may never occur.

Artesian wells in the northern PRB are integral to the area's agricultural and ranching operations. Deep wells near the Powder River that are completed in the coal aquifer likely would be affected by drawdown associated with development of CBM. Mitigation of water wells in this area could be an undertaking of considerable magnitude if existing uses are to continue. Mitigation under the terms of the water well agreement or landowner's surface use agreements would continue until the hydraulic head of the coal aquifer recovers sufficiently after development of CBM and could involve the descendents of current landowners before mitigation is completed. Artesian conditions likely would not recover unless recovery of the last 5 percent of hydraulic head occurs. Groundwater uses that rely on the existing artesian conditions in wells likely would be affected for many years.

According to WSEO records, some artesian flow in the northern PRB is associated with shallow wells. Shallow wells likely represent a shallow, local groundwater flow system that would not be affected by drawdown of the coal aquifer. However, infiltration of CBM produced water may affect the flow rate and water chemistry of shallow artesian wells. Flow rates of these shallow wells could increase while large volumes of produced water are infiltrating the surface at locations upstream or uphill of the wells.

Many issues related to water wells, including shallow artesian wells, deep water wells near the Powder River, and monitoring wells at coal mines, would depend on site-specific geologic and hydrologic conditions and existing or proposed developments. Water well and monitoring well impacts would be analyzed on a site-specific basis at the APD or POD level of analysis, as APDs and PODs for federal CBM wells are reviewed by the BLM, and the FS as appropriate. The potential effects on water wells and monitoring wells would be analyzed and site-specific mitigating measures, or monitoring requirements relating to a specific CBM well or group of CBM wells, would be developed based on the analysis. Impacts would be controlled through BLM-mandated APD conditions of approval that address landowner agreements, mitigation, monitoring, well control, casing, ventilation, and plugging procedures.

Emissions of Methane

Withdrawal of water during CBM development can depressurize the coal aquifer and induce methane release into nearby water wells completed in the coal aquifer. Individual well users in the coal aquifer may experience an increase in emissions of methane if the wells fall within an area that experiences noticeable aquifer depressurization.

Opportunities for development of groundwater may be limited in gas-bearing formations or in aquifers that contain entrained natural gas. Opportunities for development could be limited where gas is present in concentrations that are potentially explosive or have a negative effect on water quality.

Although methane is tasteless, odorless, colorless, and nontoxic to humans, its presence in groundwater can create an anoxic environment that may lead to geochemical reactions and foster bacterial growth that adversely affect the taste, odor, and appearance of the pumped water. Near-surface migration of methane may displace oxygen, giving rise to anoxic environments where undesirable, sulfate-reducing bacteria can multiply. These bacteria release hydrogen sulfide, a toxic gas (BLM 2000a). The spread of bacteria in wells and aquifers could be increased where methane migration and seepage also are increased.

When water that contains entrained natural gas is exposed to the air, gas is released from solution and can dissipate rapidly if adequate ventilation exists. However, natural gas entrained in groundwater can escape from solution and cause fire or explosion hazards in confined or poorly ventilated spaces.

Records of the first indications of methane production in monitoring wells that have experienced drops in water levels as a result of mining indicate that methane emission from the coal can occur with as little as 50 feet of head drop (Belle Ayr Mine groundwater monitoring data). Consequently, coal wells within the predicted 50-foot drawdown area may be susceptible to this impact. Methane emissions by a well pose a potential explosive safety hazard, particularly if gases can build up in an enclosed space. Well houses and basements located within the area of potential 50-foot drawdown associated with operational CBM well fields should be properly ventilated and checked periodically for methane gas.

Groundwater Chemistry

Groundwater quality within the regional aquifer systems of the PRB would not be noticeably affected under Alternative 1. Limited water quality data suggest

BEST COPY AVAILABLE

26

that as CBM produced water infiltrates unsaturated alluvium, interactions between the produced water and alluvial deposits result in an alluvial water quality very similar to naturally occurring alluvial water quality (Meyer 2002c). Any noticeable effects on groundwater quality would be expressed as effects on aquifers that would serve as injection zones during CBM development or on existing springs (which emanate from the ground and may contain groundwater derived from these aquifers).

The issues associated with the potential effects on groundwater chemistry or quality are specific to the local conditions associated with sites under evaluation for proposed activities. The effects will be analyzed on a site-specific basis at the APD and POD level of analysis, as APDs and PODs for federal CBM wells are reviewed by BLM and the FS, as appropriate. The feasibility and potential effects of proposed development would be analyzed based on local conditions and site-specific mitigating measures or monitoring requirements relating to a specific CBM well or group of CBM wells would be developed based on the analysis.

Leakage

Pumping of water at CBM wells likely would move waters with different chemistry from overlying or underlying sand layers into the coal aquifer. Movement of water associated with this leakage from surrounding layers into the coal zone has been projected by the groundwater model. No quantitative estimate of changes in groundwater chemistry can be made based on the limited baseline data from sand and coal units. Chemical processes that likely would be occurring and the effects of these changes on groundwater quality in the coal zone aquifer are described below.

Some groundwater contained in Wasatch sandstones that directly overlie coal zones likely would leak into the Fort Union coal aquifer during development of CBM under Alternative 1. Preliminary results from sampling of a limited number of monitoring well clusters indicate the potential for movement of groundwater within the Wasatch Formation downward into the Fort Union Formation (Bartos and Ogle 2002, Rice et al. 2002). Groundwater in Wasatch sandstones and coals varies somewhat from the Fort Union coal aquifer, with a slightly higher median pH, higher concentrations of TDS (1,010 mg/L versus 838 mg/L), sulfate, and manganese, but lower concentrations of barium (Bartos and Ogle 2002, Rice et al. 2002).

Procedures for drilling and completing CBM wells are strictly controlled by WOGCC and BLM requirements that ensure each formation remains as isolated as it is under natural conditions and that the integrity of the well bore remains intact. Development in accordance with these requirements is not likely to allow any leakage or mixing of groundwater in the formations penetrated.

However, leakage and mixing between aquifers with differing water quality likely has occurred where aquifer zones in existing non-CBM wells were not isolated during well completion or abandonment because of a lack of mechanical integrity, including inadequate casing, cementing, or plugging. High pH values are typical in wells contaminated with alkaline cement or bentonite (Bartos and Ogle 2002).

Many existing non-CBM well bores likely do not effectively isolate the formations penetrated and may serve as conduits for mixing of waters from different aquifers. Water wells frequently are screened over multiple aquifer zones, which would facilitate mixing of groundwater from different aquifer zones. Many older conventional oil and gas wells likely are inadequately cased, which potentially could have allowed any groundwater present to leak from one formation to another. Numerous uncased boreholes were drilled in the PRB to evaluate uranium potential and were not properly plugged, which could have allowed any groundwater present to leak through the formations that were penetrated. No comprehensive evaluation of the integrity of existing wells within the Project Area has been conducted. Many thousands of water wells, non-CBM oil and gas wells, and uncased boreholes are located within the Project Area.

Infiltration

This produced water would mix with available groundwater as it infiltrates. However, no quantitative estimate of groundwater chemistry changes can be made based on the limited baseline data from pre-CBM wells and the results of groundwater quality monitoring. Chemical processes that likely would be occurring and the effects of these changes on groundwater quality in PRB aquifers are described below.

CBM produced water that is exposed at the surface typically undergoes immediate changes in chemical composition that are the result of introducing oxygen to the water. Sulfate-rich surface waters also can mix with the extracted groundwater. Where oxygen has been introduced at the surface, iron and manganese have oxidized and precipitated, as evidenced by iron stains that are commonly associated with CBM discharge outfalls. Where CBM produced water that is rich in sodium and bicarbonate and contains barium has been mixed with sulfate-type water, barium has precipitated as barium sulfate.

Limited monitoring data from shallow alluvial wells suggest that CBM produced water that has infiltrated unsaturated alluvial materials resembles naturally occurring alluvial water quality very near the surface (Meyer 2002c). This suggests that the increased volume of water recharging the underlying aquifers of the Wasatch and Fort Union Formations would be chemically similar to alluvial groundwater. The alluvial aquifer appears to act as a "buffer," with CBM produced water introduced to the system changing to become chemically similar to the alluvial groundwater rather than the alluvial groundwater being changed by the CBM produced water.

No supporting data exist to enable an estimate of the magnitude of the "buffering capacity" of the alluvial aquifer, which could provide a projection of whether all of the anticipated CBM discharges could be "buffered" by the alluvial aquifers. However, the dissolution of gypsum (hydrous calcium sulfate) in the unsaturated zone very near the surface by infiltrating CBM produced waters likely is responsible for the "buffering action" of the alluvial aquifers. Gypsum occurs abundantly in environments characterized by considerable evaporation, such as ephemeral drainages. It is unlikely that gypsum occurring in the unsaturated zone of alluvial deposits would be depleted by infiltrating CBM produced water.

BEST COPY AVAILABLE

Dissolution of gypsum by infiltrating water would add calcium and sulfate to the water. Where barium and chloride are available in infiltrating waters, barium sulfate would precipitate. The dispersal of CBM produced water over the extensive ephemeral drainage systems in the PRB would tend to place less demand on the "buffering capacity" of the alluvial aquifers in any single location.

As CBM recharge waters percolate and mix with groundwater, an oxygen-rich environment may be created, which will promote mineral oxidation, dissolution, and other chemical reactions. Eventually, when the dissolved oxygen is depleted, a reducing environment may be established.

Impoundments

The groundwater chemistry that is characteristic of CBM produced water would change over time as it evaporates from infiltration or containment impoundments. The processes and changes that are likely to occur are described later in thes chapter under the section on Surface Water.

Water Wells

Where CBM wells are drilled in close proximity to existing water wells, water quality in existing water wells may be temporarily affected immediately after the CBM wells are drilled and completed. The WSEO has received reports of increased sediment, fines, and methane odor in wells where water is being produced from a zone shallower than the target coal. These effects were reported to be temporary, clearing up after a time.

Springs

An estimated 15 percent of the volume of CBM produced water handled by infiltration impoundments (Table 2–9) is considered in the analysis of surface water effects and the groundwater model to represent the contribution of CBM produced water to shallow lateral flows and subsequent discharge to springs and surface drainages. Under Alternative 1, CBM produced water that flows laterally as shallow groundwater could mix with shallow groundwater or surface water from natural sources. However, no quantitative estimate of possible changes in groundwater chemistry for springs can be made. Chemical processes that likely would occur and the effects of these changes on groundwater quality in PRB aquifers are described below.

Where CBM produced water mixes with oxygen-rich, near-surface waters, iron and manganese in the produced water would likely oxidize and precipitate. Barium likely would precipitate as barium sulfate where CBM produced water that is rich in sodium and bicarbonate and contains barium is mixed with sulfate-type water typical of springs.

CBM operations are not expected to have any impact on the water quality of Moyer Springs because discharge water is not likely to encroach on the recharge area of the spring. Water from Moyer Springs is of calcium sulfate chemical type, with concentrations of total dissolved solids in the 1,000 mg/L to 2,000 mg/L range (Hodson et al. 1973). CBM produced water likely would be of equal or better quality. Therefore, even if some CBM discharge water recharged Moyer Springs, CBM operations should not adversely affect the water quality.

CBM Drilling Fluids

Drilling fluids are not expected to have any effect on the Tertiary aquifer system. The WOGCC and BLM requirements for well drilling procedures ensure that each formation remains as isolated as under natural conditions and that the integrity of the well bore remains intact, protecting groundwater quality in aquifers drilled by CBM wells. The enlarged well bore in open-hole completions is designed so that it does not disrupt the structural integrity of the coal seam, because production of CBM depends on the integrity of the cleats (the system of small fractures that occur naturally in the coal).

Drilling fluids do not contain constituents that would contaminate the formations surrounding the well bore of a CBM well. A mixture of water, native mud, and bentonite usually makes up the drilling fluid or drilling mud. Small amounts of biodegradable polymer additives or potassium chloride salts may be added to the mud to clean the hole and stabilize the clay.

The drilling mud is in contact with the formations surrounding the uncased well bore for only a short time. The drilling fluids are in contact with the well bore before it is cased during a period of 1 to 3 days while the well is being drilled. The well bore is isolated from surrounding formations by casing cemented into place when the depths where casing is to be set are reached. The well bore is flushed with water before drilling continues. The coal zone is then drilled using water or air only. The finished hole may be flushed with water to remove coal fines before it is lined with tubing.

Hydraulic Fracturing

Small fractures are generated during well completion by hydraulic fracturing when the producing formation immediately surrounding the CBM well bore does not contain enough natural cleats or fractures to facilitate movement of gas toward the well. In hydraulic fracturing, tiny grains of sand, aluminum pellets, beads of glass, or similar materials are carried in suspension by pressurized water and forced out into the formation through perforations in the well's production casing. Only a limited area surrounding the CBM well bore is affected by this activity. Hydraulic fracturing is designed so that it does not disrupt the structural integrity of the coal seam.

Fracturing fluids do not contain constituents that would contaminate the producing formation. Fluids used in hydraulic fracturing may or may not be acidic, depending on the characteristics of the producing formation.

Hydraulic fracturing is strictly controlled so that methane is directed toward the well bore. This procedure is designed to concentrate methane near the well bore and would not induce methane to migrate away from the well bore toward existing water wells. The use of hydraulic fracturing to complete CBM wells is not likely to release methane into the groundwater. To date, no impacts of hydraulic fracturing on existing water wells have been documented, based on a 1998 survey of state oil and gas agencies by the Ground Water Protection Council (EPA 2002a).

Hydraulic fracturing, if used to complete CBM wells, is not likely to have any effect on groundwater quality. No cases of groundwater contamination associated

30

with hydraulic fracturing of CBM wells have been substantiated and a recent study by EPA concluded that the potential threats to underground sources of drinking water (USDWs) posed by hydraulic fracturing of CBM wells appear to be low and do not justify further study (EPA 2002a). EPA found that thousands of CBM wells are fractured annually but did not find persuasive evidence that any drinking water wells had been contaminated by CBM fracturing (EPA 2002a). The PRB was included in this study. None of the constituents used in hydraulic fracturing have been documented as affecting water wells or groundwater supplies in the PRB.

Injection

Groundwater flow systems in potential injection zones below the coal zone aquifer likely would be dominated by regional flows. Groundwater in these deeper aquifer units has not been developed as extensively as in aquifer units above the coal zone and in the coal zone itself. However, high yields of 200 to 300 gpm, especially in the Tullock aquifer, make the zone attractive for municipal and industrial uses. Many water supply wells for mines are completed in the Tullock aquifer (AHA and Greystone 2002).

The effects of groundwater additions that would be associated with injection operations are not well known. The injection of CBM produced water into disposal wells could affect the chemistry or quality, quantity, and temperature of groundwater contained in the injection zone or other aquifers within the disposal well's area of influence.

Groundwater Flow Systems

The groundwater resources of the PRB are vast (Table 3–5) and the reduction in volume of recoverable groundwater in storage within the PRB under Alternative 1 would not be noticeable. Regional flow within and out of the PRB also would not be noticeably affected under Alternative 1. Any noticeable effects on local groundwater flow systems would be expressed as effects on existing springs, flowing (artesian) wells, or groundwater discharge areas.

Groundwater Storage

Before wells are developed, aquifers are in a state of dynamic equilibrium where recharge and discharge virtually balance over long periods (Lohman 1972). A natural groundwater flow system approximates steady-state flow where there is no change in head over time (Lohman 1972).

The groundwater flow system of the PRB continues to be affected by activities that extract groundwater, preventing the flow equilibrium from being reestablished. Only a portion of the groundwater extracted would be replaced through additional recharge or reduced discharge. The remaining portion of the groundwater extracted would come from storage. Depending on the water handling practices used within each sub-watershed under Alternative 1, an estimated 15 to 33 percent of the pumped water would be recharged to the groundwater system as a result of infiltration along creeks and below impoundments or injection (Table 4–1).

31

CBM produced water would consist primarily of groundwater pumped from storage within the developed coals and water that leaked from nearby sand layers into the coals as a result of depressurization. Most of the produced water likely would come from leakage into the coal from sand layers above and below the coal zone. Groundwater that can be recovered from the coal by pumping would be removed early in the life of a CBM well.

Nearly 1.4 billion acre-feet of recoverable groundwater exist within the Wasatch and Fort Union Formations in the PRB (Table 3–5). The majority of recoverable groundwater in the PRB is contained in sandstones within these formations. The projected CBM water production from 2002 to 2017, about 3 million acre-feet (Table 2–8), is less than 1 percent of the recoverable groundwater (almost 750 million acre-feet) in the sands and coals of the Tongue River-Wasatch aquifer and only 0.2 percent of the recoverable groundwater stored within the Wasatch and Fort Union Formations of the PRB (Table 3–5).

Downgradient Aquifers

Both shallow and deep aquifers of the Northern Great Plains aquifer system are located downgradient of the Project Area (Downey 1986). Shallow Tertiary aquifers flow north and east toward the northern PRB in Montana with some discharge in the Gillette area (Lowry et al. 1986). The effects on these shallow downgradient aquifers would be similar to the effects already described in this chapter for these aquifers within the Project Area.

Groundwater moves within deeper, lower Tertiary aquifers from southeastern Johnson County toward northeastern Natrona County to replace hydrocarbons pumped from oil fields in Natrona County (Lowry et al. 1986). This groundwater flow system is not hydraulically connected with the Tertiary coal zone aquifer, and would not be affected by CBM development.

Deep aquifers downgradient of the Project Area include the lower Cretaceous and the underlying Madison. Neither of these aquifer zones is hydraulically connected with the Tertiary coal zone aquifer. CBM development within the PRB is not likely to affect either of these deep aquifers.

Groundwater in the Tertiary coal zone aquifer is moving to the north and east and is not a significant source of recharge to the underlying lower Cretaceous aquifers (Lowy et al. 1986). The lower Cretaceous aquifers are recharged principally because of leakage from the underlying Madison aquifer (Lowry et al. 1986).

Groundwater moves within the underlying Madison aquifer toward discharge areas in eastern North Dakota and South Dakota (Lowry et al. 1986). This groundwater flow system is not hydraulically connected with the Tertiary coal zone aquifer and would not be affected by CBM development.

Pumping of Aquifers

Local movement of groundwater near a pumping well or wells can be rapid, in contrast to the slow movement of groundwater within a natural system. For example, a 1994 pump test of a municipal well near Gillette produced 85 gpm with a drawdown of 53 feet over 470 minutes. In contrast, the infiltration of meteoric water downward along the hydraulic gradient into the Fort Union Formation at this same location can be inferred to require more than 50 years to travel less than 1,500 feet. This estimate is based on dating groundwater in the Fort Union Formation as sub-modern, or older than 1952 (Bartos and Ogle 2002, Rice et al. 2002), and the as-built diagram for the municipal well (Wester-Wetstein and Associates, Inc. 1999).

Flowing Artesian Wells and Springs

Flowing artesian wells consist of shallow and deep wells. The effects on flowing artesian wells under Alternative 1 would differ based on whether wells tap shallow local groundwater or deeper groundwater within the coal zone aquifer.

Wells completed in shallow aquifers that flow locally would not be likely to be affected by drawdown of the coal zone aquifer during CBM development. These wells likely would be affected, however, by the increased availability of shallow groundwater where the CBM produced water is infiltrating. Increased flows would be the likely effects on wells completed in shallow aquifers.

An estimated 15 percent of the volume of CBM produced water handled by infiltration impoundments (Table 2–9) is considered in the analysis of effects to surface water and the groundwater model to represent the contribution of CBM produced water to shallow lateral flows and subsequent discharge to springs and surface drainages.

Deep flowing artesian wells completed in the coal zone aquifer or sandstone layers in hydraulic connection with the coal zone aquifer likely would be affected by drawdown of the coal zone aquifer during CBM development. Decreased flows or no flow would be the likely effects on wells completed in deep aquifers. Changes in flows are not quantified in this analysis.

The effects on springs that issue from shallow sources would be similar to the effects on shallow flowing artesian wells described above. Increased availability of shallow groundwater caused by the infiltration of CBM produced water likely would cause new springs and seeps to develop downgradient of locations where infiltration is occurring. Possible effects on water chemistry are described in the subsection on groundwater chemistry.

The public has expressed concern about the potential effects of CBM development on springs that issue from clinker outcrops, such as the Moyer Springs located north of Gillette in Section 30 Township 51N. Range 71W. Moyer Springs is located at the base of an exposed clinker deposit in the outcrop area of the Roland-Smith coal seam. Recharge of the springs is through surface infiltration and lateral movement of water from adjacent clinker and alluvium. The springs issue along a low-permeability zone at the contact between the clinker and the coal. Large areas of clinker are exposed northeast and southeast of Moyer Springs (Williams 1978). This exposure allows a large amount of recharge to the clinker by infiltration of rainfall and snowmelt. Hodson et al. (1973) reported a flow of 200 gallons per minute from Moyer Springs.

No decrease in flows would be anticipated under Alternative 1 where the springs result from flow along a near-surface zone of low permeability that intercepts the surface. Many springs in the Project Area, including Moyer Springs, represent this type. A contact of low permeability inhibits flow between the clinker and the coal. The presence of a low-permeability zone between the clinker and the coal channels water in the clinker to the spring rather than recharging the coal. A decrease in recharge to the spring (which is not projected to occur under Alternative 1) could reduce flow for this type of spring.

Groundwater Discharge Areas

Groundwater has been discharging to the surface in many areas near the Powder River, where the hydraulic head from the deep coal aquifer intercepts the surface, and flow along the natural groundwater gradient is toward the river. A reduction in hydraulic head within the coal aquifer projected during development of CBM under Alternative 1 likely would reduce groundwater discharge and base flows in surface drainages within the Powder River's drainage basin. Groundwater discharge likely would not recover until the hydraulic head in the coal aquifer recovers sufficiently after development of CBM. Recovery of hydraulic head within the coal aquifer also is discussed earlier under the results of the groundwater model.

Negligible infiltration would be anticipated where containment ponds or reservoirs constructed in upland areas would be used to handle CBM produced water. It is unlikely that new springs would develop or shallow infiltrated water would resurface near properly engineered and constructed containment impoundments, provided facilities are sited and constructed in accordance with WDEQ, WSEO, and WOGCC requirements.

The use of infiltration impoundments or flow-through stock reservoirs during surface discharge associated with CBM development could cause new springs to develop where a near-surface zone of low permeability intercepts the surface, unless these water handling facilities are sited to minimize this potential effect. Siting in accordance with WDEQ and WSEO requirements and avoidance of sites where a zone of low permeability intercepts the surface downhill or downgradient from an area where considerable infiltration of CBM produced water is occurring would minimize the potential for shallow infiltrated water to resurface.

One detailed model study for the LX Bar drainage (AHA and Greystone 2002) showed that the potential contributions to surface flows from increased groundwater discharge would be much less than 1 cfs if all CBM produced water in the LX Bar drainage were held in infiltration impoundments. However, the same detailed study also showed that the potential rise in groundwater in the shallow Wasatch sands would be up to 50 feet in the immediate vicinity of impoundments and up to 10 feet in areas that are several hundred feet from impoundments. This rise would occur if all CBM produced water in the LX Bar drainage were held in infiltration impoundments.

The current water table may be shallow in many areas where infiltration impoundments could be constructed. The increase in water level in these areas may be exhibited as groundwater discharge to the surface, standing water in areas that did not previously display this condition, or as wetland development, unless the percentage of CBM wells where produced water held in infiltration impoundments is carefully controlled. The effects of impoundment and infiltration of

34

BEST COPY AVAILABLE

CBM produced water would need to be analyzed on a site-specific basis to ensure that water table and groundwater discharge effects are carefully balanced or mitigated during development of CBM.

The issues associated with the impacts of dewatering (pumping) and infiltration on springs, pre-CBM artesian wells, and groundwater discharge areas are specific to the local conditions associated with sites under evaluation for proposed activities. The effects would be analyzed on a site-specific basis at the APD or POD level of analysis, as APDs and PODs for federal CBM wells are reviewed by BLM, and the FS as appropriate. The feasibility and potential effects of proposed development will be analyzed based on local conditions. Then, site-specific mitigating measures or monitoring requirements that relate to a specific CBM well or group of CBM wells would be developed based on the analysis.

Alternative 2A

Alternative 2A involves the same number of CBM wells and volume of water produced as Alternative 1. Except for the differences in recharge that would occur based on variations in water handling options (discussed below), the effects on groundwater resources would be similar to Alternative 1.

The recharge effect was evaluated in this analysis by examining the area of affected alluvial drainages and the probable range of vertical infiltration rates into the Wasatch Formation below the creeks and ponds. The total discharge from CBM operations was obtained from the projection for each sub-watershed (Table 2–8). This CBM produced water would be managed according to the water handling options identified for each sub-watershed under Alternative 2A (Table 2–21). The net recharge was calculated using the percentage of the produced water handled by each method and the projected conveyance loss. The calculated net recharge volume, on a year-by-year basis, was divided by the projected CBM development area within each sub-watershed to obtain an equivalent recharge rate for the area in inches per year. Depending on the water handling practices used within each sub-watershed under Alternative 2A, an estimated 28 to 43 percent of the pumped water would be recharged to the shallow groundwater system as a result of infiltration along creeks and below impoundments. This recharge under Alternative 2A is compared below with the values input into the model under Alternative 1.

Alternative 2A involves different handling of the water produced by CBM operations in certain sub-watersheds. The proportion of water handled by infiltration impoundments and injection would be emphasized under Alternative 2A. Under Alternative 2A, less CBM produced water would be discharged to surface drainages than under Alternative 1. More CBM produced water would be handled using infiltration impoundments, containment impoundments, LAD, and injection than under Alternative 1. In addition, under Alternative 2A there would be a 5 percent reduction from Alternative 1 in the volume of produced water handled using LAD in the Crazy Woman Creek sub-watershed, with a corresponding increase in the volume of produced water managed by injection. In the Salt Creek sub-watershed, the elimination of surface discharge would be replaced by other water handling methods, in particular infiltration impoundments and injection.

35

The differences in water handling methods generally would result in an increase in infiltration at the ground surface compared with Alternative 1. This increase would be small, with some watersheds (Antelope Creek, Upper Cheyenne River and Upper Belle Fourche River) actually showing small decreases. Increases in infiltration of between 12 and 28 percent would occur in the Salt Creek, Upper Powder River, Crazy Woman Creek, Clear Creek, Middle Powder River, and Little Powder River sub-watersheds compared with Alternative 1. Under Alternative 2A, the projected increase in surface infiltration would be a small fraction of an inch per year in the various sub-watersheds. These small changes would have a negligible effect on groundwater conditions within these drainages. An increased percentage of water in the Crazy Woman Creek and Salt Creek sub-watersheds would be managed by injection into aquifer units below the coal zone.

Alternative 2B

Alternative 2B involves the same number of CBM wells and volume of water production as Alternative 1. Except for the differences in recharge that would occur based on variations in water handling options (discussed below), the effects on groundwater resources would be similar to Alternative 1.

The recharge effect was evaluated in this analysis by examining the area of affected alluvial drainages and the probable range of vertical infiltration rates into the Wasatch Formation below the creeks and ponds. The total discharge from CBM operations was obtained from the projection for each sub-watershed (Table 2–8). This CBM produced water would be managed according to the water handling options identified for each sub-watershed under Alternative 2B (Table 2–22). The net recharge was calculated using the percentage of the produced water handled by each method and the projected conveyance loss. The calculated net recharge volume, on a year-by-year basis, was divided by the projected CBM development area within each sub-watershed to obtain an equivalent recharge rate for the area in inches per year. Depending on the water handling practices used within each sub-watershed, under Alternative 2B an estimated 21 to 30 percent of the pumped water would be recharged to the shallow groundwater system as a result of infiltration along creeks and below impoundments (Table 4–1). This recharge under Alternative 2B is compared below with the values input into the model under Alternative 1.

Alternative 2B involves different handling of the water produced by CBM operations in certain sub-watersheds. An upper limit would be set on the proportion of water handled by infiltration impoundment under Alternative 2B, and active treatment of CBM-produced water would be included as a water handling method. Under Alternative 2B, less CBM produced water would be discharged to surface drainages than under Alternative 1. More CBM-produced water would be handled using infiltration impoundments, containment impoundments, LAD, and injection than under Alternative 1. In the Salt Creek sub-watershed, the elimination of surface discharge would be replaced by increased use of other methods, in particular infiltration impoundments and injection.

The difference in water handling methods for Alternative 2B generally would result in a small change in infiltration at the ground surface compared with Alternative 1. The changes in infiltration associated with Alternative 2B are generally small, with the largest increases in infiltration occurring in the Crazy Woman Creek and Middle Powder River sub-watersheds. The Upper Tongue River, Salt Creek, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds would show small decreases in infiltration. Under Alternative 2B, this projected increase in surface infiltration would involve a small fraction of an inch per year in the various sub-watersheds. These small changes would have a negligible effect on groundwater conditions within these drainages. The percentage of water managed by injection by injection into aquifer units below the coal zone would increase in the Crazy Woman Creek and Salt Creek sub-watersheds.

Alternative 3

Under Alternative 1, the largest numbers of new federal CBM wells would be drilled in the Upper Powder River and Upper Belle Fourche River sub-watersheds (24,898 of 39,367 projected wells under Alternative 1). The exclusion of federal wells from these sub-watersheds under Alternative 3 represents a 77 percent reduction in the Upper Powder River sub-watershed (14,531 wells) and a 43 percent reduction in the Upper Belle Fourche River sub-watershed (2,531 wells). The percentage reduction in wells also would be high in the Middle Powder River sub-watershed, where the reduction would be 79 percent (or 757 wells). More than 1,000 wells also would be eliminated in each of the following sub-watersheds: Crazy Woman Creek (1,986 wells); Clear Creek (1,265 wells); Little Powder River (1,076 wells); and Antelope Creek (1,041 wells). Relatively lower percentage reductions in wells would occur in the Upper Tongue River sub-watershed (17 percent) and in the Clear Creek sub-watershed (34 percent).

Water handling options would be same as under Alternative 1. Depending on the water handling practices used within each sub-watershed, an estimated 15 to 33 percent of the groundwater produced from CBM operations would be released to surface drainages or impoundments (Table 4–1).

Table 2–34 shows the projected quantity of water that would be removed during CBM development occurring from 2002 through 2017, summarized by sub-watershed. Within the Project Area, water production would be projected to pe[illegible] during 2005, at a rate of 212,919 acre-feet per year. Although water production would decline substantially in all sub-watersheds under Alternative 3, the percentage reduction in water production, compared with Alternative 1, would be less than is shown in Chapter 2. Under Alternative 3, individual wells would yield more water to maintain sufficient drawdown and allow methane to be produced. The projected CBM water production from 2002 to 2017, about 1.6 million acre-foot (Table 2–34), represents about 0.1 percent of the recoverable groundwater stored within the Wasatch and Fort Union Formations of the PRB (Table 3–5).

The extent of drawdown in the coal units would also change. The greatest change would occur in the sub-watersheds with the largest percentages of federal wells.

The areal extent of the 25-foot drawdown contour would tend to decrease in areas where large concentrations of federal wells would be drilled under Alternative 1 for example, in the Upper Powder River and Upper Belle Fourche River sub-watersheds. It is less likely that state and fee wells would be developed around large undeveloped federal blocks unless there would be enough wells to maintain adequate drawdown and produce methane.

The volume of produced water that would recharge shallow bedrock and alluvium would diminish proportionately with the decline in water production. The areal extent of recharge would be reduced to exclude areas that would have contained new federal CBM wells, such as in the Upper Powder River, Upper Belle Fourche River, and Crazy Woman Creek sub-watersheds. In areas that would have had very high concentrations of federal wells under Alternative 1, the extent of drawdown in the coals would be considerably less because of non-development under Alternative 3, resulting also in less drawdown within the overlying Wasatch sands.

Cumulative Effects

Regionally, the various PRB coal zones merge, split, and pinch out laterally in complex patterns (Flores 1999, Flores et al. 1999). Coal zone aquifers within the Project Area occur as layers that, individually, are continuous only over an average distance of 10 miles. Although regional groundwater flow toward the north occurs, it is interrupted where coal aquifers are discontinuous, and groundwater is discharged in local flow systems. Where coal aquifers are discontinuous, flow in local groundwater systems (bedrock, alluvial, and clinker) appears to dominate over the flow in a regional system (Rankl and Lowry 1990). Most of this local groundwater discharge from bedrock aquifers occurs above stream level and is lost through evapotranspiration or is consumed as soil moisture and does not make a noticeable contribution to surface drainages.

The areal extent and magnitude of drawdown effects on coal zone aquifers and overlying or underlying sand units in the Wasatch Formation also would be limited by the discontinuous nature of the different coal zones within the Fort Union Formation and sandstone layers within the Wasatch Formation. Where a coal zone aquifer or sandstone layer pinches out laterally, drawdown effects also would be interrupted somewhat, although leakage from nearby layers would continue. This discontinuous nature of the various coal zones would tend to limit the areal extent of drawdown in Montana, outside the Project Area, that is associated with CBM development in the PRB within Wyoming.

Computer modeling of groundwater resources could not capture the level of subsurface detail in the PRB. Hydrogeologic layers included in the model assumed that the coal beds are more continuous and are of a more uniform thickness than actually occur in the PRB to develop a reasonable model for this analysis. The drawdown effects on coal zone aquifers predicted by the model represent the maximum areal extent and magnitude of drawdown, assuming continuous layers of variable thickness. Drawdown in discontinuous layers likely would be limited by the continuous areal extent of the layer. Where coal aquifers are mined, such as in the area near the state line, the mine is established as a drain node in the

BEST COPY AVAILABLE

model. A quantitative estimate of CBM-associated drawdown near a mine area is difficult to predict.

Alternative 1

The cumulative impacts on groundwater resources from activities associated with CBM development and with coal mining were included in the groundwater model and impact analysis described earlier in this chapter. Reasonably foreseeable groundwater conditions could not be considered separately for proposed CBM development. Therefore, the analysis included the impacts of existing and reasonably foreseeable CBM development and mining. Reasonably foreseeable coal mining, as depicted in mine plans and existing effects of coal mines on groundwater resources were incorporated into the groundwater model. Projected and existing or already authorized development of CBM also was incorporated into the groundwater model. Projected water production, shown in Table 2–8 and already discussed in this chapter, represented the total for existing and authorized CBM wells and CBM wells projected under Alternative 1.

Development of CBM through 2018 and coal mining through 2033 would remove 4 million acre-feet of groundwater from the coal zone aquifer (AHA and Greystone 2002). Projected water production from CBM development (about 3 million acre-feet, from Table 2–8) and projected groundwater removed during mining (about 1 million acre-feet, estimated on a yearly basis from 1976 to 2033 in the groundwater model), cumulatively represent 0.5 percent of the recoverable groundwater stored in the Wasatch-Tongue river sands and coals (nearly 750 million acre-feet, from Table 3–5). All of the groundwater projected to be removed during reasonably foreseeable CBM development and coal mining would represent less than 0.3 percent of the total recoverable groundwater in the Wasatch and Fort Union Formations within the PRB (nearly 1.4 billion acre-feet, from Table 3–5).

Northeast of Sheridan, Wyoming, the model projects some effects of the proposed project extending into Montana for a short distance; however, these projections near the Montana-Wyoming state line are based on limited data. Drawdowns of 100 feet in the Fort Union coal zone are projected to extend 1 to 3 miles into Montana (Figure 4–6). The model projects recovery in the coal zone to a 20-foot drawdown by 2060 for most areas in Montana that would be affected by the project (Figures 4–26 through 4–29).

Cumulatively, groundwater would be removed from the coal aquifers that underlie the Project Area, temporarily reducing or eliminating the hydraulic pressure head in the coal. An estimated 15 to 33 percent of the groundwater removed would infiltrate the surface and recharge the shallow aquifers above the coals. Redistribution of pressure within the coals after water production ends would allow the hydraulic pressure head to recover within approximately 50 feet or less of pre-project levels within 25 years after the project ends. Complete recovery of water levels likely would take tens to hundreds of years, depending on the location. This drop in hydraulic pressure head likely would cause a slight reduction in regional groundwater discharge to surface drainages within the Powder River system, including drainages downstream of the Project Area, in Montana.

Wasatch aquifers that overlie the coals also would be affected by development. As the coal is de-pressurized by water removal during mining or development of CBM, water contained in deep Wasatch sands would leak into the coals. Water levels in the deep Wasatch sands would be lowered, but the drawdown in the deep Wasatch sands likely would be less than 10 percent of the level that would occur in the coal. Water levels in the deep Wasatch sands also would recover after development ends. Recovery to within 25 feet of pre-operational levels would occur 25 years after development ends. Complete recovery of water levels likely would take tens to hundreds of years, depending on location. Water levels (the water table) in shallow Wasatch sands are not likely to be lowered during development except in areas of shallow coal and also would recover after water production ends. In some areas, water levels in very shallow Wasatch sands likely would rise initially, up to 50 feet in the immediate vicinity of impoundments and up to 10 feet at distances of several hundred feet from impoundments or surface drainages that receive CBM discharge. This rise would occur through enhanced recharge from infiltration of CBM produced water.

Impacts between CBM and coal development are differentiated below. Some similarities and some differences in the impacts are associated with mining and development of CBM.

Effects on the Coal Aquifer

Both mining and CBM development result in partial removal of the water from the coal seam. In mining, the coal is removed so that impacts to the coal aquifer are considerable. Immediately adjacent to active mine pits, the water from the coal aquifer will drain into the pit, which would dewater the aquifer. The extent of coal aquifer dewatering and de-pressurization associated with mining depends largely on the continuity of the coal near the mine and its overall permeability (a function of fracturing). In areas of high coal permeability, which tend to coincide with major fracture trends, the extent of drawdown may be several miles. Areas of limited coal drawdown related to mining are associated with lower permeability or less fracturing in the coal.

Pumping groundwater from the coal induces depressurization during active development of CBM. Pumping removes water (and methane) but leaves the coal itself essentially undisturbed. Depressurization within the coal caused by development of CBM would be more widespread than is caused by mining because development of CBM would cover a much larger area. Mining is limited to an area within 2 to 3 miles of the coal outcrop because of the ratios of overburden and coal strips. Development of CBM is projected to cover most of the Project Area.

Impacts to Aquifers Stratigraphically Above the Coal

The sand aquifers of the Wasatch Formation are hydrologically separated from the coal zone within the Fort Union Formation by low-permeability claystones. During mining, the shallower aquifers (the overburden) must be removed to expose the coal. Impacts to these aquifers in mined areas are considerable. Immediately adjacent to active mine pit areas, the Wasatch sands intercepted by excavations may drain into the pit and become dewatered. The areal extent of dewatering in the Wasatch aquifer associated with mining depends largely on the conti-

40

BEST COPY AVAILABLE

nuity of the sand units near the mine and whether these sand units are intercepted by mining. There are many examples of overburden monitoring wells completed in relatively isolated sand units that show little influence from nearby mining. Drawdown in the coal aquifer induced by mining, in turn, induces vertical leakage from the overlying Wasatch sands, contributing to drawdown in these sands.

During developmentof CBM, the Wasatch sand aquifers would not be directly affected by excavations or surface-disturbing activities. Leakage from the Wasatch sands into the coal would be enhanced by development of CBM. Because of the limited hydraulic communication between the coal and the overlying Wasatch sands, a considerable period (typically several years) may pass before noticeable drawdown in the sands occurs. The areal extent of drawdowns in the Wasatch sands from development of CBM would be much greater than is caused by mining.

Changes in Infiltration Rates and Recharge

During mining, the overburden (including Wasatch sand aquifers) and coal aquifers are removed and replaced with backfill material (spoils). Infiltration and recharge through the spoils are likely to be higher than in the original, undisturbed materials. The aquifers would remain essentially undisturbed during development of CBM and the infiltration and recharge mechanisms also would be unchanged. Water discharged to the surface from CBM operations would increase recharge to alluvial aquifers and underlying Wasatch sands.

Changes in Groundwater Quality

Induced leakage of groundwater from the Wasatch sands into the coal zone aquifer would occur as a result of both mining and development of CBM. The possible effects when groundwater from the Wasatch sands mixes with water contained in the coal zone aquifer are discussed earlier in the section on Groundwater, under Alternative 1 — Groundwater Chemistry.

After mining, the coal and Wasatch sand aquifers are replaced with spoils that have the potential to change the quality of groundwater. Water removed from the coal during development of CBM would recharge alluvial and Wasatch sand aquifers. The possible effects associated with the mixture of CBM produced water with groundwater in the shallow aquifer system are discussed earlier in the section on groundwater, under Alternative 1 — Groundwater Chemistry.

Discharge of Produced Waters

Both mining and development of CBM result in the collection and discharge of water to surface drainages. Mine inflow water is first stored in sediment ponds to reduce sediment picked up in the pit. Much of this water is used for dust suppression and is not discharged to surface drainages, except during certain storm events. The discharge water from sediment ponds potentially would have higher TDS values and be of lower quality as a result of sediment mixing and concentration by evaporation. CBM discharges are essentially sediment-free (as produced from CBM wells), although discharge to surface drainages can increase sediment loading caused by increased stream erosion.

41

Fort Union Aquifers Underlying the Coal Zone

Mining may affect aquifers underlying the coal zone by potentially influencing recharge water quality. Groundwater withdrawals from lower aquifers for mine use also may affect these aquifers. Development of CBM may affect lower aquifers by inducing upward leakage from them into the coal during coal depressurization. These cumulative influences were included in the groundwater model.

Moyer Springs

The potential effect to Moyer Springs flows by proposed surface mining has been recognized, as removal of the Wasatch Formation and alluvial overburden during mining operations may decrease recharge to the spring. Accordingly, the Dry Fork Mine Permit requires Dry Fork Coal Company to protect the clinker aquifer that feeds Moyer Springs.

Alternative 2A

The cumulative impacts on groundwater resources would be similar to those described under Alternative 1, except as noted below.

Projected development of CBM and development of CBM existing or authorized before this analysis also were incorporated within the groundwater model. Projected water production, shown in Table 2–8 and already discussed in this chapter, represented total water production for existing and authorized CBM wells and CBM wells projected under Alternative 2A.

Cumulatively, groundwater would be removed from the coal aquifers underlying the Project Area, temporarily reducing or eliminating the hydraulic pressure head in the coal. An estimated 28 to 43 percent of the groundwater removed would infiltrate the surface and recharge the shallow aquifers above the coal.

Alternative 2B

The cumulative impacts on groundwater resources would be similar to those described under Alternative 1, except as noted below.

Projected development of CBM and development of CBM existing or authorized before this analysis also were incorporated within the groundwater model. Projected water production, shown in Table 2–8 and already discussed in this chapter, represented total water production for existing and authorized CBM wells and CBM wells projected under Alternative 2B.

Cumulatively, groundwater would be removed from the coal aquifers underlying the Project Area, temporarily reducing or eliminating the hydraulic pressure head in the coal. An estimated 21 to 30 percent of the groundwater removed would infiltrate the surface and recharge the shallow aquifers above the coals.

Alternative 3

The cumulative impacts on groundwater resources would be similar to but much less in magnitude than those described under Alternative 1, except as noted below.

Alternative 3 assumes that no new federal CBM wells would be completed, except in areas of potential drainage. The substantial reduction in projected new CBM wells under this alternative would reduce water production in all sub-watershed. The reductions would be greatest in the Upper Powder River and Upper Belle Fourche River sub-watersheds where the highest numbers of new federal CBM wells would have been drilled. The areal extent of the 25-foot drawdown contour would tend to decrease in areas where large numbers of federal wells were projected to be drilled under Alternative 1.

Projected development of CBM and development of CBM existing or authorized before this analysis also were incorporated within the groundwater model. Projected water production, shown in Table 2–34 and already discussed in this chapter, represented total water production for existing and authorized CBM wells and CBM wells projected under Alternative 3.

Cumulatively, groundwater would be removed from the coal aquifers underlying the Project Area, temporarily reducing or eliminating the hydraulic pressure head in the coal. An estimated 15 to 33 percent of the groundwater removed would infiltrate the surface and recharge the shallow aquifers above the coals.

Surface Water

Potential effects to surface water resources may include: (1) changes in surface water quality and suitability to meet designated uses; (2) changes in the quantity and distribution of surface flows; (3) erosion and degradation of the drainage network; and (4) increased sedimentation. The magnitude of effects to surface water resources would depend on a number of factors, including the quantity and timing of CBM produced water discharges, the surface water quality at the point of downstream diversions, existing and future downstream designated uses, and the specific mix of water handling options implemented to prevent CBM discharges from reaching the main stem streams.

The overall effects of the proposed project on surface water resources would be similar among alternatives; however, the magnitude of these effects would vary because of the different water handling percentages proposed for each alternative.

Surface Water Impact Analysis

A major beneficial use of surface water in the Project Area is the production of irrigated crops. Therefore, the surface water impact analysis focuses on the potential effects to the suitability for irrigation of surface waters in the Project Area from proposed discharges of CBM produced water. The effects of CBM produced water (quantity and quality) on soils, vegetation, wetland and riparian areas, and aquatic life are discussed in subsequent sections.

The key water quality parameters for predicting the potential effects of CBM development on irrigated agriculture are sodicity (as measured in the sodium adsorption ratio, SAR) and salinity (as measured by electrical conductivity, EC). Instream numerical targets for these parameters, therefore, would facilitate modeling and interpretation of impacts under the various alternatives. Ideally, those numerical targets would be in the form of numerical water quality standards, in other words, values with regulatory authority. At this time, with the exception of waters that flow from Wyoming into South Dakota, there are no regulatory water quality standards for these parameters applicable to the water bodies addressed in this analysis, or for water bodies downstream in Montana that are likely to receive flows of CBM produced water from Wyoming.

Therefore, because of the importance of this issue, the regulatory agencies with jurisdiction for the potentially affected water bodies have begun the process of quantifying the SAR and EC values they believe will be needed to ensure protection of irrigated agriculture in and downstream of the Project Area. In May 2002, for example, the Northern Cheyenne Tribe adopted numerical water quality standards for SAR and EC that apply to waters within the reservation, which include flows in the Tongue River from Wyoming. Although these tribal standards will not attain Clean Water Act regulatory status until the EPA approves them, the adopted numerical standards clearly set out the Tribe's determination of the water quality needed to protect irrigated agriculture on the Reservation.

Wyoming's current permitting process incorporates the numeric water quality standards for EC and SAR adopted for water bodies downstream in South Dakota, specifically drainages in the Upper Cheyenne and Upper Belle Fourche River sub-watersheds. Wyoming and Montana have entered an interim MOC for waters downstream in Montana to protect the downstream water quality in the Powder and Little Powder River sub-watersheds while allowing for development of CBM in both states. This MOC is presented in Appendix B. Interim thresholds are established for EC in the Powder River at the state line, based on monitoring data collected at the gauging station in Moorhead, Montana. The criteria for EC are expressed in monthly maximum values that are not to be exceeded. The two states are also concerned with SAR and bicarbonate, but lack sufficient data to establish threshold criteria. Under the MOC, monitoring of the Little Powder River will include EC, SAR, and TDS to evaluate whether levels of these constituents change appreciably from historical records. The State of Wyoming would be required to undertake a cause investigation in the event that significant changes in baseline conditions are detected to determine if CBM discharge is responsible. Wyoming may be required to adjust its regulatory position with the permitting process to ensure compliance with the spirit of the agreement. Wyoming, through its NPDES permitting process, is restricting the amount of CBM discharge water that reaches the main stems to meet the short-term goal of the MOC. Discharges are limited through such mechanisms as pond storage, channel loss, and other consumptive uses. Furthermore, as a matter of policy, WDEQ has elected to impose its antidegradation policy on all CBM discharges. This policy results in effluent limitations in NPDES permits for discharges of CBM produced water that equate to 20 percent of the available increment between low-flow pol-

BEST COPY AVAILABLE

lutant concentrations and the relevant standards (assimilative capacity) for critical constituents. A separate antidegradation policy for barium, in which the assimilative capacity is basin-specific, is also applied to CBM discharges. Montana has accepted Wyoming's antidegradation policies to be protective of Montana's water quality.

Montana has initiated a process for developing and adopting water quality standards for SAR and EC as well, with the goal of having a final decision by the Montana Board of Environmental Review by December of 2002. Within the Montana process, MDEQ has proposed two approaches: one would assign a single set of SAR and EC values to each of the potentially affected water bodies (option 1) and the second would assign a series of values that would be applicable to the mainstem of the Tongue River (option 2). MDEQ lists a range of values to be considered by the Board for each approach. In addition, a coalition of environmental and irrigation interest groups, collectively known as the "Petitioners," has proposed a set of numerical SAR and EC standards. The Petitioners include: the Tongue River Water Users Association; the Tongue and Yellowstone Irrigation District; the Buffalo Rapids Irrigation Project; and the Northern Plains Resource Council. The Petitioners' proposal takes an approach similar to MDEQ's option 2. Finally, some time ago, South Dakota's Department of Environment and Natural Resources (SDDENR) adopted numerical SAR and EC standards that are applicable statewide.

There are, then, five sets of numerical standards for SAR and EC now under consideration or applicable to the water bodies that are addressed in this analysis: the Northern Cheyenne Tribe's adopted water quality standards; Montana's option 1; Montana's option 2; the Petitioners' proposal; and South Dakota's adopted statewide water quality standards. Together, these five sets of values present a wide range of numerical values, and Table 4–2 displays the full range. It includes both the least and most restrictive proposed upper limits, where applicable, for SAR and EC. Because the water quality standards development process is still under way for key water bodies addressed in this analysis, however, it would be inappropriate for the lead or cooperating agencies to select specific numerical values within the range and to apply only those selected values in evaluating potential impact scenarios. Instead, this document uses the full range of potential SAR and EC values as the boundaries to display outputs from surface water modeling.

The information displayed should be applied with the three following considerations: First, it should not be assumed that any SAR or EC value within the range displayed will be deemed an appropriate level of protection for the existing or anticipated irrigated agricultural uses in these basins. Second, the water quality standards process involves adoption by a state or tribe followed by EPA review and approval, and state- or tribally adopted limits will not have Clean Water Act regulatory status until approved by EPA. Third, the water quality standards process is still under way and it is not possible to predict the outcome of the process.

Nevertheless, while the eventual outcome of this water quality standards process is uncertain at present, it may be useful to note the specific SAR and EC values adopted by the Northern Cheyenne Tribe and the SDDENR, and those proposed by the MDEQ and the Petitioners and to include those values within specific im-

YS

pact scenarios evaluated. These SAR and EC values were developed with assistance from advisors with expertise in the effects of salinity and sodicity on irrigated agriculture. Therefore, it would not be unreasonable to view these values as providing a fair estimate of the range of SAR and EC values that may eventually be judged as providing an appropriate level of protection for irrigated agriculture in the sub-watersheds addressed in this analysis. The specific EC and SAR values proposed or adopted for these sub-watersheds are presented in Appendix H, allowing for application of specific, proposed, or adopted numerical standards in the evaluation of various impact scenarios.

Another factor to be considered in applying the information displayed is the significant distinction between the approach to surface water modeling applied to alternatives analyzed in this EIS and the approach that eventually will be used in calculating discharge limits for future, specific CBM development projects. The modeling approach used in this document begins with an assumed water management method for the proposed development under each alternative and, applying a series of assumptions (see discussion below), predicts a resultant in-stream water quality. That predicted water quality modeling output is then displayed against the full range of potential SAR and EC limits for each sub-watershed, with no assessment as to the appropriateness of any specific value within the range. The water quality-based approach that will be used to calculate future NPDES permitting requirements, instead, will begin with appropriate and specific in-stream water quality targets, such as approved water quality standards. Then, through the TMDL process, the standards will be translated into discharge limits for specific CBM development projects.

The standards will serve as the regulatory basis for controlling CBM discharges. The water quality-based permitting approach that will implement those standards is, therefore, different from the predictive modeling approach used in this analysis. That is, the water quality-based approach will begin with a desired in-stream water quality and, using that as the target, will calculate the CBM discharge limits needed to ensure the desired in-stream water quality. Finally, where the TMDL process identifies assimilative capacity for a water body, the capacity will be allocated through the TMDL among the appropriate governmental entities along the water body. Where a tribe is one of the appropriate governmental entities, EPA has a trust responsibility to ensure that a fair and meaningful portion of the available assimilative capacity is reserved for the tribe.

Table 4–2 summarizes the highest and lowest standards proposed for or applicable to the sub-watersheds addressed in this analysis. Construction of this table considered the full range of values proposed in the Montana standards process now underway, the adopted Northern Cheyenne standards, South Dakota's standards, and the limits applied by the WDEQ to waters that flow downstream into South Dakota. The proposed limits apply to individual sub-watersheds and have been suggested for seasons of the year. For example, different limits have been proposed for the irrigation season. However, because a single irrigation season has not been agreed upon, the limits have been lumped together. South Dakota applies water quality standards for EC and SAR year-round. The limits shown in Table 4–2 were incorporated into the discussion of impacts that follows. Because CBM discharges to the Upper Powder River, Clear Creek, Crazy Woman Creek, and Salt Creek sub-watersheds have the potential to flow into the Middle Powder

BEST COPY AVAILABLE

46

River sub-watershed in Montana, Montana's proposed limits for the Powder River have also been applied to these sub-watersheds. WDEQ applies limits in the Upper Cheyenne (also applicable to Antelope Creek) and the Upper Belle Fourche sub-watersheds in authorizing discharge permits for CBM produced waters to protect the most sensitive crop (such as alfalfa) that may be grown downstream (Beach 2002).

Table 4–2 Summary of Proposed Limits for Surface Water Impact Analysis

Sub-Watershed	Most Restrictive Proposed Limit (MRPL)		Least Restrictive Proposed Limit (LRPL)	
	SAR	EC	SAR	EC
Tongue	0.5	500	10	2,500
Little Powder	3.0	1,000	10	3,000
Powder	2.0	1,000	10	3,200
Belle Fourche	10[1]	2,000[1]	10[2]	2,500[2]
Cheyenne	10[1]	2,000[1]	10[2]	2,500[2]

Notes:
1. WDEQ limit applied to waters that flow downstream into South Dakota.
2. South Dakota's existing water quality standard.

Modeling Approach

The spreadsheet model used in the surface water impact analysis employs a steady-state mass-balance approach to estimate EC concentrations and SAR values after stream flows and CBM produced water discharges have mixed. This steady-state approach is commonly used by the regulatory agencies in predicting possible effects of point source discharges on receiving waters. Input parameters for the model were developed from analysis of existing data on stream flow and water quality, existing CBM production, and representative coal water quality data that incorporate reasonably conservative assumptions. The input parameters are described briefly below, and in greater detail in the Surface Water Quality Analysis Technical Report (SWQATR), which was prepared in support of this document. The spreadsheet model provided a conservative, yet reasonable, estimate of the impacts of the proposed development of CBM on surface water quality in and downstream of the Project Area.

Model Input Parameters

Stream Flow

Representative flow rates for streams in the Project Area were obtained from analysis of the historical record at USGS stream gauging stations (Kuhn 2002). Base-flow conditions in the streams are represented by the low of the mean monthly flows and were used in the impact analysis for predicting water quality effects under worst-case conditions. This information is presented in Table 3–8.

47

Stream Water Quality

Representative EC and SAR values for streams in the Project Area were obtained from analysis of the historical record at USGS stream monitoring stations (Meyer 2002b). This information is presented in Table 3–11. EC and SAR values that correspond to mean monthly flow conditions were used in the surface water impact analysis.

CBM Discharge Rate

BLM analyzed water production data from existing wells that were downloaded from the WOGCC web page to project total water production on an annual and an over the life of the project basis by sub-watershed (BLM 2002). For the Upper Belle Fourche, Antelope Creek, and the Upper Cheyenne River sub-watersheds, the number of wells and corresponding flow rate per well in the peak year of water production were used as input parameters in the surface water impact analysis. The average peak discharge rate in these sub-watersheds is 7.0, 11.9, and 9.6 gpm per well, respectively. A value of 6.2 gpm per well, which represents a basin-wide (Wyoming and Montana) average production rate during the peak year of water production, was used in the Powder River, Little Powder River, and Upper Tongue River sub-watersheds.

CBM Water Quality

BLM has summarized and modeled EC and SAR values for CBM produced water by sub-watershed (BLM 2002). This information is shown in Figure 3–1. Mean values for EC and SAR were used in the surface water impact analysis. The EC and SAR values used in the impact analysis in the Upper Cheyenne River sub-watershed represent a flow-weighted average of the combined discharges from the Antelope Creek and Upper Cheyenne River sub-watersheds. The EC and SAR values used in the impact analysis in the Middle Powder River sub-watershed represent a flow-weighted average of the combined discharges from the Salt Creek, Clear Creek, Crazy Woman Creek, Upper Powder River, and Middle Powder River sub-watersheds.

Model Assumptions

The following assumptions form the framework for evaluating the impacts in this analysis:

- Discharge of CBM produced water to surface drainages was assumed to result in a conveyance loss of 20 percent. This value is considerably lower than the values derived from studies of surface water losses in creek flows within several drainages of the PRB (Meyer 2000b, AHA 2001b). These previous studies were limited geographically to specific areas of the PRB and did not account for certain times of year (especially winter) when evaporation and evapotranspiration losses would be reduced. Therefore, the value used in this model for conveyance loss was decreased between the DEIS and FEIS to account for these conditions. The remaining 80 percent of the CBM produced water discharged to surface drainages was assumed to reach the main stem in each sub-watershed.

- Where produced water is discharged to infiltration impoundments designed to allow infiltration, 15 percent of the water would resurface and contribute to in-channel flow; the remainder would infiltrate into the shallow aquifer system.

- CBM produced water that is actively treated was assumed to be 100 percent consumptively used because of its higher quality.

- Water produced from CBM wells and managed through containment, LAD, and injection would not have direct effects on quantity and quality of surface water because, by definition (see Chapter 2), none of the discharged water under these options would reach drainages in the sub-watersheds. Indirect effects from implementation of these water handling options, such as potential effects to waterfowl from evaporative concentration of CBM discharged waters in containment impoundments and potential effects on soils and vegetation from LAD, are discussed in subsequent sections.

- The percentage of CBM water production handled by active treatment, containment, LAD, and injection, and the proportion of water lost to the shallow aquifer system from infiltration impoundments is summarized collectively as Managed Water Loss.

- It was assumed that the sodium and salinity content of water produced from CBM wells are the target constituents that control the usefulness of the water for irrigation of crops. Irrigation is the primary beneficial use for the majority of water resources in the sub-watersheds expected to have the greatest potential for CBM development, especially with respect to the Montana portion of the PRB. Sodium causes osmotic stress to plants and destroys the texture of clayey soils; these combined effects make sodium content, and especially SAR, a point of emphasis when evaluating impacts to water resources from CBM water. The salinity of irrigation water, as expressed by EC, affects crop productivity.

- EC and SAR values for resulting mixtures of existing stream water and CBM discharge water under various flow conditions are compared with the MRPL and LRPL listed in Table 4–2. A comparison was also made between the existing and resultant water quality using the Ayers and Westcot (1985) irrigation suitability diagram, which compares water quality before and after mixing in terms of suitability for irrigation and especially for impacts on soils irrigated with the water. Elevated values of SAR may reduce the permeability of soil, thereby reducing the rate of water infiltration. The Ayers-Westcot diagram was also used to evaluate the proportion of CBM discharge that could reasonably occur under various flow conditions without causing potential effects to infiltration. The proportion of CBM discharge specified includes managed water losses described under each alternative. The irrigation season is defined for this analysis as the period April 1 through October 31.

- The impact analysis did not consider changes in water quality that may occur as the CBM discharge flows overland toward the main stem streams or as it infiltrates to shallow groundwater systems and is discharged to surface flows. Water quality and flow monitoring results from the tributary monitoring program suggest that CBM discharges tend to pick up salts (EC) from the soils and alluvium as they flow down tributary channels and that SAR values decrease (AHA 2001a). Thus, CBM discharges improve between the discharge point and the receiving stream with respect to SAR but worsen with respect to EC. Therefore, using the water quality of the CBM discharge provides a more conservative estimate of the impact on surface water of the main stems.

- The impact analysis did not consider individual constituent (sodium, calcium, and magnesium) values in determining the resultant SAR values. This assumption is inherently conservative (Greystone and ALL 2002).

Comparison of Alternatives

Surface water flow is expressed in this analysis in cubic feet per second, or cfs. The water produced from wells is expressed in gallons per minute, or gpm. One cfs is equivalent to 448.83 gpm. Large flows or volumes of water are expressed as acre-feet. One acre-foot is equivalent to 43,650 cubic feet, or 325,851 gallons.

Alternative 1

Under Alternative 1, CBM produced water flows would be handled through direct discharge to surface drainages, passive treatment before surface discharge, discharge to upland and bottomland infiltration impoundments, discharge to containment impoundments, LAD, and injection (Table 2–9). With surface discharge, CBM produced water flows would be gathered for discharge at outfalls authorized in accordance with guidance and requirements of the State of Wyoming (WDEQ and possibly WSEO). Passive treatment would be employed primarily to remove iron, and under Alternative 1, would occur only in the Upper Tongue River, Middle Powder River, and Clear Creek sub-watersheds.

BLM analyzed water production data from existing wells downloaded from the WOGCC web page to project total water production on an annual and an over the life of the project basis by sub-watershed (BLM 2002). This analysis assumed that all of the 12,024 existing wells would produce water before 2002 and that water production for the last of the existing wells to be drilled ends after 2007. Water production from the last of the 39,367 new wells to be drilled is assumed to conclude at the end of 2017. Projected CBM water production under Alternatives 1, 2A, and 2B is shown in Table 2–8.

Under Alternative 1, the maximum CBM water volume produced annually is expected to increase from an estimated 109,429 acre-feet per year produced from existing CBM wells in 2001 to an estimated 386,336 acre-feet per year in 2006. The peak year of water production by sub-watershed varies, and these years were modeled in the surface water impact analysis to evaluate effects from CBM produced water discharges.

Alternative 2A

Under Alternative 2A, CBM produced water would be handled by the same methods specified in Alternative 1 (Table 2–21). Use of upland and bottomland infiltration impoundments would be emphasized. With the exception of a proportion of direct surface discharge in the Upper Belle Fourche River sub-watershed authorized under existing NPDES permits, requirements for passive treatment, primarily for iron, would be imposed in all sub-watersheds. There would be no surface discharge in the Salt Creek sub-watershed. The volume of water produced and the peak year of water production would be the same as under Alternative 1.

Alternative 2B

Under Alternative 2B, CBM produced water would be handled by the same methods specified in Alternative 1 (Table 2–22). Use of active treatment, such as reverse osmosis, or ion exchange systems, to amend the produced water to meet water quality standards prior to discharge would be emphasized. Some level of active treatment would be implemented in all sub-watersheds except for the Upper Belle Fourche River sub-watershed. The level of treatment would depend on the constituents of concern and downstream designated uses. With the exception of a proportion of direct surface discharge in the Upper Belle Fourche River sub-watershed authorized under existing NPDES permits, requirements for passive treatment, primarily for iron, would be imposed in all sub-watersheds. There would be no surface discharge in the Salt Creek sub-watershed. The volume of water produced and the peak year of water production would be the same as under Alternative 1.

Alternative 3

Under Alternative 3, no new Federal CBM wells would be completed, except for potential drainage situations. Water handling options would be the same as under Alternative 1. Passive treatment would be employed primarily to remove iron, and under Alternative 3, would occur only in the Upper Tongue River and Clear Creek sub-watersheds. Projected CBM water production under Alternative 3 is shown in Table 2–34.

Under Alternative 3, the maximum CBM water volume produced annually is expected to increase from an estimated 109,429 acre-feet per year produced from existing CBM wells in 2001 to an estimated 212,919 acre-feet per year in 2005. The peak year of water production by sub-watershed varies, and these years were modeled in the surface water impact analysis to evaluate effects from discharges of CBM produced water.

Effects from Each Alternative by Sub-Watershed

Results of the impact analysis under each alternative are presented below by sub-watershed. A discussion of potential impacts to surface water quantity and quality follows. The Tongue, Powder, and Little Powder River sub-watersheds are discussed in a subsequent section to address the combined effects of CBM development in both Wyoming and Montana.

The projected impacts of CBM development on surface water quality in each sub-watershed were derived with the use of four graphs, which are described below. Only those graphs depicting potential impacts at the stateline stations under the preferred alternative (Tongue River at Decker, Montana, Middle Powder

51

River at Moorhead, MT, and Little Powder River at Weston, Wyoming) are included herein; graphs for all sub-watersheds are depicted in the SWQATR. The first graph plots ambient and projected EC for mean monthly and 7Q10 flows. The second graph plots ambient and projected SAR for mean monthly and 7Q10 flows. Both these graphs include lines showing the MRPL and LRPL to facilitate evaluation of the impacts. The next two graphs plot ambient and projected water quality for both EC and SAR in relation to the Ayers-Westcott EC-SAR threshold that represents "no reduction in the rate of infiltration" as well as to the MRPL and LRPL. Water quality that meets the proposed EC and SAR limits as well as the Ayers-Westcott threshold should fall to the left of the proposed EC limit, below the proposed SAR limit and below and to the right of the diagonal line on the graphs. The first of these graphs plots ambient and projected EC and SAR for mean monthly and 7Q10 flows. The second plots the projected EC and SAR for incremental proportions of CBM discharge. The input parameters used in developing the graphs are summarized in Appendicies C and D of the SWQATR.

When considering the potential impacts to surface water resources discussed below for each sub-watershed under the various alternatives, the reader should be aware that the mass balance model used in this analysis is a tool for comparison of alternatives, and analysis of relative contributions of cumulative impacts. However, due to a lack of data regarding chemical transport relationships and conveyance loss it may not accurately predict likely impacts on resultant water quality (See Appendix E, SWQATR). Samples collected since the onset of CBM production in the Upper Belle Fourche River and Little Powder River sub-watersheds have not detected changes in ambient stream water quality which were predicted by the mass balance model, and actual impacts may be less then the mass balance model predicts. The magnitude of the model results can not be verified based upon actual measured water quality data. Adequate protection of existing uses and water quality standards can only be accomplished through direct monitoring of stream water quality to measure the effects of CBM discharge.

It is also important to note that the Ayers-Westcot diagram incorporates a relationship between SAR and EC, which recognizes that as salinity increases the potential impacts of SAR decrease. This relationship is not unbounded however, because of the potential impact of rainfall on sodic soils. Rainfall can cause SAR problems in surface soil because of the differential way in which EC and SAR respond to a rain event (significant lowering of the EC and little change in the SAR). This rain-on-sodic-soil problem is addressed in a number of the standards proposals (see Appendix H) through adoption of an absolute maximum SAR (i.e. the standard "caps" the Ayers-Westcot EC/SAR relationship). It is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached in the alternatives analyses in this document. This may help explain situations where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Upper Belle Fourche Sub-Watershed

Results of the impact analysis in the Upper Belle Fourche River sub-watershed under each alternative are presented in Table 4–3. Potential impacts are discussed below.

BEST COPY AVAILABLE

Alternative 1

Under Alternative 1, the peak year of water production in the Upper Belle Fourche River sub-watershed would occur in 2006, when 7,630 wells would be producing at an average rate of 7.0 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Belle Fourche River sub-watershed during the peak year of CBM water production is about 49 cfs (35,479 acre-feet/year). Volumes of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Table 4–3 Surface Water Impact Analysis of the Upper Belle Fourche River Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	10[1]	2,000[1]	10[2]	2,500[2]	2.3	6.8	2,755	51	8.1	1,051
2A	10[1]	2,000[1]	10[2]	2,500[2]				64	8.1	1,034
2B	10[1]	2,000[1]	10[2]	2,500[2]				64	8.1	1,034
3	10[1]	2,000[1]	10[2]	2,500[2]				37	8.1	1,081

Notes:

1. WDEQ limit applied to waters that flow downstream into South Dakota.
2. South Dakota's existing water quality standard.

Mean monthly EC values in the Upper Belle Fourche River currently exceed the MRPL and LRPL during low-flow conditions. Mean monthly SAR values currently are less than the MRPL and LRPL under similar flow conditions. After mixing, the resultant stream flow under low-flow conditions would consist almost entirely of CBM produced water. The resultant EC would decrease, whereas the SAR would increase from existing conditions. The existing 7Q10 flow is calculated as zero, such that the resultant water quality under these flow conditions would be represented by the quality of CBM produced water, if discharges were to occur during critical low-flow periods.

Under modeled conditions, the resultant water quality in the Upper Belle Fourche River sub-watershed at Moorcroft, Wyoming, during all months of the year and during 7Q10 flow conditions would be adequate to meet the MRPL for both EC and SAR that the WDEQ has adopted in its NPDES permitting process to be protective of downstream irrigation. A comparison of the resultant mixed water quality with the Ayers-Westcot diagram indicates that infiltration would be reduced during some months of the irrigation season (April, and July through October) as well as during 7Q10 flow conditions. During the low monthly flow, only a small fraction (10 percent) of the CBM discharge could occur without causing potential effects to infiltration. Irrigators currently tend to use water from the Belle Fourche River during high flow events. During low flow and 7Q10 flow conditions, water from the Belle Fourche River is not likely to be diverted for irrigation purposes. During average flow conditions, essentially 100 percent of the CBM discharge could occur without causing potential effects to irrigation.

Based on modeled results, under certain flow conditions, impacts to the suitability for irrigation of the Upper Belle Fourche River from CBM development may occur. However, as noted previously, samples collected since the onset of CBM production in the Upper Belle Fourche River sub-watershed have not detected changes in ambient stream water quality which were predicted by the mass balance model, and actual impacts may be less then the mass balance model predicts. The magnitude of the model results can not be verified based upon actual measured water quality data. Adequate protection of existing uses and water quality standards can only be accomplished through direct monitoring of stream water quality to measure the effects of CBM discharge. In addition, discharge permits issued by the WDEQ would be the mechanism that would identify the appropriate mix of water handling methods to be employed to meet the standards. Producers also may decide to limit development in the Upper Belle Fourche River sub-watershed to meet permit requirements rather that utilizing other water management practices (infiltration, treatment, LAD). As a result, even though the model predicts impacts, ultimately those predicted impacts to the irrigation suitability of the Upper Belle Fourche River from CBM development in Wyoming under Alternative 1 may not occur.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be less than under Alternative 1, primarily because of the increase in surface discharge and reduced use of infiltration and containment impoundments for water handling. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Belle Fourche River sub-watershed during the peak year of CBM water production is about 61 cfs (44,168 acre-feet/year). Under Alternative 2A, impacts to surface water quality in the Upper Belle Fourche River sub-watershed at Moorcroft, Wyoming, would be similar to the results obtained under Alternative 1.

Alternative 2B

As shown in Tables 2–21 and 2–22, there is no difference between Alternatives 2A and 2B that would affect the modeled output in the Upper Belle Fourche River sub-watershed. Thus, potential impacts described above for Alternative 2A would be the same under Alternative 2B.

Alternative 3

Under Alternative 3, the peak year of water production in the Upper Belle Fourche River sub-watershed would occur in 2005, when 6,160 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Belle Fourche River sub-watershed during the peak year of CBM water production is about 35 cfs (25,342 acre-feet/year). Impacts to surface water quality in the Upper Belle Fourche River sub-watershed would be similar to those described under Alternative 1.

BEST COPY AVAILABLE

Antelope Creek Sub-Watershed

Results of the impact analysis in the Antelope Creek sub-watershed under each alternative are presented in Table 4-4. Potential impacts are discussed below.

Table 4-4 Surface Water Impact Analysis of the Antelope Creek Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	10[1]	2,000[1]	10[2]	2,500[2]	0.2	2.6	2,354	12	7.0	924
2A	10[1]	2,000[1]	10[2]	2,500[2]				13	7.0	923
2B	10[1]	2,000[1]	10[2]	2,500[2]				13	7.0	923
3	10[1]	2,000[1]	10[2]	2,500[2]				7	7.0	937

Notes:
1. WDEQ limit applied to waters that flow downstream into South Dakota.
2. South Dakota's existing water quality standard.

Alternative 1

Under Alternative 1, the annual water production in the Antelope Creek sub-watershed would peak in 2004, when 925 wells would be producing at an average rate of 11.9 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Antelope Creek sub-watershed during the peak year of CBM water production is about 12 cfs (8,689 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Mean monthly EC values in Antelope Creek currently exceed the MRPL, but are less than the LRPL during low-flow conditions. Mean monthly SAR values currently are less than the MRPL and LRPL under similar flow conditions. After mixing, the resultant stream flow under low-flow conditions would consist almost entirely of CBM produced water. The resultant EC would decrease, whereas the SAR would increase from existing conditions. The existing 7Q10 flow could not be computed because of a lack of data; therefore, the resultant water quality under these flow conditions is assumed to be represented by the quality of CBM produced water, if discharges were to occur during critical low-flow periods.

Under modeled conditions, the resultant water quality in the Antelope Creek sub-watershed near Teckla, Wyoming, during all months of the year and during 7Q10 flow conditions would be adequate to meet the MRPL for both EC and SAR that WDEQ has adopted in its NPDES permitting process to be protective of downstream irrigation. A comparison of the resultant mixed water quality with the Ayers-Westcot diagram indicates some effects to infiltration, primarily during the lowest flow months of September through February and during 7Q10 flow conditions. During the low monthly flow, only a small fraction (less than 10 percent) of the CBM discharge could occur without causing potential effects to infiltration. Irrigators currently tend to use water from the Antelope Creek during high flow events. During low flow and 7Q10 flow conditions, water from the Antelope Creek is not likely to be diverted for irrigation purposes. During average flow conditions, essentially 100 percent of the CBM discharge could occur without causing potential effects to irrigation.

Based on modeled results, under certain flow conditions, impacts to the suitability for irrigation of Antelope Creek from CBM development may occur. However, as noted previously, samples collected since the onset of CBM production in the Upper Belle Fourche River and Little Powder River sub-watersheds have not detected changes in ambient stream water quality which were predicted by the mass balance model, and actual impacts may be less then the mass balance model predicts. The magnitude of the model results can not be verified based upon actual measured water quality data. Adequate protection of existing uses and water quality standards can only be accomplished through direct monitoring of stream water quality to measure the effects of CBM discharge. In addition, discharge permits issued by the WDEQ would be the mechanism that would identify the appropriate mix of water handling methods to be employed to meet the standards. Producers also may decide to limit development in the Upper Belle Fourche River sub-watershed to meet permit requirements rather than utilizing other water management practices (infiltration, treatment, LAD). As a result, even though the model predicts impacts, ultimately those predicted impacts to the irrigation suitability of Antelope Creek from CBM development in Wyoming under Alternative 1 may not occur.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be less than under Alternative 1, primarily because of the increase in surface discharge and reduced use of infiltration and containment impoundments. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Antelope Creek sub-watershed during the peak year of CBM water production is about 13 cfs (9,413 acre-feet/year). Under Alternative 2A, impacts to surface water quality in the Antelope Creek sub-watershed would be similar to the results obtained under Alternative 1.

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily caused by the implementation of active treatment. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Antelope Creek sub-watershed during the peak year of CBM water production is about 12 cfs (8,689 acre-feet/year). Impacts to surface water quality in the Antelope Creek sub-watershed would be similar to those described for Alternative 1. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Antelope Creek sub-watershed would occur in 2005, when 561 wells would be producing at an average rate of 11.9 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Antelope Creek sub-watershed during the peak year of CBM water production is about 7 cfs (5,068 acre-feet/year). Impacts to surface water quality in the Antelope Creek sub-watershed would be similar to those described under Alternative 1.

Upper Cheyenne River Sub-Watershed

The surface water impact analysis of the Upper Cheyenne River sub-watershed incorporates the CBM produced water discharges from the Antelope Creek sub-watershed under each of the alternatives to predict water quality conditions at the USGS gauging station on the Cheyenne River at Riverview, Wyoming.

Results of the impact analysis in the Upper Cheyenne River sub-watershed under each alternative are presented in Table 4–5. Potential impacts are discussed below.

Table 4–5 Surface Water Impact Analysis of the Upper Cheyenne River Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	10[1]	2,000[1]	10[2]	2,500[2]	0.4	8.7	4,127	18	6.9	881
2A	10[1]	2,000[1]	10[2]	2,500[2]				19	6.9	876
2B	10[1]	2,000[1]	10[2]	2,500[2]				19	6.9	877
3	10[1]	2,000[1]	10[2]	2,500[2]				12	6.9	896

Notes:
1. WDEQ limit applied to waters that flow downstream into South Dakota.
2. South Dakota's existing water quality standard.

Alternative 1

Under Alternative 1, the peak year of water production in the Upper Cheyenne River sub-watershed would occur in 2003, when 1,471 wells would be producing at an average rate of 11.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Cheyenne River sub-watershed during the peak year of CBM water production is about 18 cfs (13,033 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Mean monthly EC values in the Upper Cheyenne River currently exceed the MRPL and LRPL during low-flow conditions. Mean monthly SAR values currently are less than the MRPL and LRPL under similar flow conditions. After mixing, the resultant stream flow under low-flow conditions would consist almost entirely of CBM produced water. Water quality in the stream would improve with the addition of CBM produced water. The resultant EC and SAR would decrease from existing conditions. The existing 7Q10 flow could not be computed because of a lack of data; however, the 7Q10 flow calculated at the USGS station on the Cheyenne River at Edgemont, South Dakota, is zero. Therefore, it is assumed that the resultant water quality under these flow conditions at the Riverview, Wyoming station would be represented by the CBM produced water quality, if discharges were to occur during critical low-flow periods.

Under modeled conditions, with the exception of during the highest flow months of September through December and during 7Q10 flow conditions, the resultant water quality in the Upper Cheyenne River sub-watershed near Riverview, Wyoming would be adequate to meet the MRPL for EC that the WDEQ has adopted in its NPDES permitting process to be protective of downstream irrigation. The resultant SAR would be adequate to meet the MRPL during all months. A comparison of the resultant mixed water quality with the Ayers-Westcot diagram indicates some effects to infiltration during the irrigation season, primarily during low flow in April and during 7Q10 flow conditions. During the low monthly flow, only a small fraction (10 percent) of the CBM discharge could occur without causing potential effects to infiltration. During average flow conditions when diversions for irrigation are likely to occur, essentially 100 percent of the CBM discharge could occur without causing effects to irrigation.

Based on modeled results, under certain flow conditions, impacts to the suitability for irrigation of the Upper Cheyenne River from CBM development may occur. However, as noted previously, samples collected since the onset of CBM production in the Upper Belle Fourche River and Little Powder River sub-watersheds have not detected changes in ambient stream water quality which were predicted by the mass balance model, and actual impacts may be less then the mass balance model predicts. The magnitude of the model results can not be verified based upon actual measured water quality data. Adequate protection of existing uses and water quality standards can only be accomplished through direct monitoring of stream water quality to measure the effects of CBM discharge. In addition, discharge permits issued by the WDEQ would be the mechanism that would identify the appropriate mix of water handling methods to be employed to meet the standards. Producers also may decide to limit development in the Upper Cheyenne River sub-watershed to meet permit requirements rather than utilizing other water management practices (infiltration, treatment, LAD). As a result, even though the model predicts impacts, ultimately those predicted impacts to the irrigation suitability of the Upper Cheyenne River from CBM development in Wyoming under Alternative 1 may not occur.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be less than under Alternative 1, primarily because of the increase in surface discharge and reduced use of infiltration and containment impoundments. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Cheyenne River sub-watershed during the peak year of CBM water production is about 19 cfs (13,757 acre-feet/year). Under Al-

BEST COPY AVAILABLE

ternative 2A, impacts to surface water quality would be similar to the results obtained under Alternative 1.

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in surface discharge and reduced use of infiltration and containment impoundments. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Cheyenne River sub-watershed during the peak year of CBM water production is about 18 cfs (13,033 acre-feet/year). Impacts to surface water quality would be similar to those described for Alternative 1. Additional water would be available to support beneficial use based on the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Upper Cheyenne River sub-watershed would occur in 2003, when 1,030 wells would be producing at an average rate of 11.0 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Cheyenne River sub-watershed during the peak year of CBM water production is about 12 cfs (8,689 acre-feet/year). A comparison of the resultant quality of mixed water with the Ayers-Westcot line indicates no effects to infiltration except during 7Q10 flow conditions. Under Alternative 3, the resultant EC would not be adequate to meet the LRPL during several months of the irrigation season as well as during 7Q10 flow conditions.

Upper Powder River Sub-Watershed

Results of the impact analysis in the Upper Powder River sub-watershed under each alternative are presented in Table 4–6. Potential effects are discussed below.

Table 4–6 Surface Water Impact Analysis of the Upper Powder River Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	2.0	1,000	10	3,200	75	7.8	3,400	211	15.3	2,606
2A	2.0	1,000	10	3,200				144	13.4	2,812
2B	2.0	1,000	10	3,200				138	13.1	2,837
3	2.0	1,000	10	3,200				121	12.2	2,934

Alternative 1

Under Alternative 1, the peak year of water production in the Upper Powder River sub-watershed would occur in 2006, when 15,822 wells would be producing at an average rate of 6.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Powder

River sub-watershed during the peak year of CBM water production is about 135 cfs (97,749 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Mean monthly EC values in the Upper Powder River currently exceed the MRPL and LRPL under low-flow conditions. Mean monthly SAR values currently exceed the MRPL, but are less than the LRPL under similar flow conditions. The resultant stream flow under low-flow conditions would nearly triple from natural stream flow. The resultant EC would decrease, whereas the SAR would increase from existing conditions. The existing 7Q10 flow is calculated as zero; therefore, it is assumed that the resultant water quality under these flow conditions would be represented by the quality of CBM produced water if discharges were to occur during critical low-flow periods.

Under modeled conditions, the resultant water quality in the Upper Powder River sub-watershed at Arvada, Wyoming, would not be adequate to meet the MRPL for EC at any time. It would be adequate to meet the LRPL for EC during all months, as well as during 7Q10 flow conditions, if it should be determined that the MRPL and LRPL criteria are protective of downstream irrigation. The resultant SAR would not be adequate to meet the MRPL at any time and would not be adequate to meet the LRPL during the irrigation months of July through October or during 7Q10 flow conditions. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates no effects to infiltration during the irrigation months or during 7Q10 flow conditions. During the low monthly flow, essentially all of the CBM discharge could occur without causing potential effects to infiltration. As stated previously, it is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached under this alternative. This may help explain the situation where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Based on modeled results, under certain flow conditions, impacts to irrigated agriculture in the Upper Powder River sub-watershed from CBM development in Wyoming under Alternative 1 may occur. Although the resultant impacts fall outside the boundaries of the LRPL during some months, BLM recognizes the uncertainty concerning the determination of water quality standards for EC and SAR. If a standard at the low end of the range of proposed values is selected, additional mitigation may be necessary for CBM discharges to this sub-watershed to occur. Potential mitigation measures that could be implemented in order to meet the ultimate regulatory standards for EC and SAR once those standards have been identified include CBM produced water storage during the irrigation months and surface discharge during the non-irrigation months. In addition, discharge permits issued by the WDEQ would be the mechanism that would identify the appropriate mix of water handling methods to be employed to meet the standards. Producers also may decide to limit development in the Upper Powder River sub-watershed to meet permit requirements rather than utilizing other water management practices (infiltration, treatment, LAD). As a result, even though the model predicts impacts, ultimately those predicted impacts to the irrigation suitability of the Upper Powder River from CBM development in Wyoming under Alternative 1 may not occur.

BEST COPY AVAILABLE

60

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because the increase in infiltration impoundments and reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Powder River sub-watershed during the peak year of CBM water production is about 68 cfs (49,237 acre-feet/year). The resultant flow and water quality would be similar to that described under Alternative 1, but the magnitude of change from existing water quality would be less based on the reduced CBM discharges. Under Alternative 2A, impacts to surface water quality would be similar to those described under Alternative 1.

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and implementation of active treatment. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Powder River sub-watershed during the peak year of CBM water production is about 63 cfs (45,616 acre-feet/year). The resultant flow and water quality would be similar to that described under Alternative 1, but the magnitude of change from existing water quality would be less based on the reduced CBM discharges. Impacts to surface water quality would be similar to those described for Alternative 1. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Upper Powder River sub-watershed would occur in 2005, when 5,332 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Powder River sub-watershed during the peak year of CBM water production is about 45 cfs (32,583 acre-feet/year). Impacts to surface water quality would be similar to those described under Alternative 1.

Clear Creek Sub-Watershed

Results of the impact analysis in the Clear Creek sub-watershed under each alternative are presented in Table 4–7. Potential impacts are discussed below.

Alternative 1

Under Alternative 1, the peak year of water production in the Clear Creek sub-watershed would occur in 2006, when 2,257 wells would be producing at an average rate of 6.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Clear Creek sub-watershed during the peak year of CBM water production is about 10 cfs (7,241 acre-feet/

year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Table 4–7 Surface Water Impact Analysis of the Clear Creek Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	2.0	1,000	10	3,200	62	1.5	1,276	73	5.4	1,522
2A	2.0	1,000	10	3,200				66	3.1	1,378
2B	2.0	1,000	10	3,200				65	2.8	1,359
3	2.0	1,000	10	3,200				70	4.5	1,469

Mean monthly EC values in Clear Creek currently exceed the MRPL but are less than the LRPL during low-flow conditions. Mean monthly SAR values currently are less than the MRPL under similar flow conditions and are less than the LRPL during 7Q10 flow conditions. After mixing, the resultant stream flow under low-flow conditions would increase moderately from the natural level. The resultant EC and SAR would increase from existing conditions.

Under modeled conditions, with the exception of during high flow in June, the resultant water quality in the Clear Creek sub-watershed near Arvada, Wyoming, would not be adequate to meet the MRPL for both EC and SAR. It would, however, be adequate to meet the LRPL for both constituents, if it should be determined that the MRPL and LRPL criteria are protective of downstream irrigation. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates no effects to infiltration except during 7Q10 flow conditions. During the low monthly flow, essentially all of the CBM discharge could occur without causing potential effects to infiltration. As stated previously, it is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached under this alternative. This may help explain the situation where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Based on the higher stream water quality and value as a source of irrigation in the Clear Creek sub-watershed, current WDEQ policy would not allow any new discharge permits that would result in any decrease in baseline water quality. Because of WDEQ's policy, it is expected that water quality in Clear Creek would be preserved at near current levels.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Clear Creek sub-watershed during the peak year of CBM water production is about 4 cfs (2,896 acre-feet/year). Under Alternative 2A, the resultant SAR would be adequate to meet the MRPL during high flows in April through June but not during the remainder of the irrigation season, when natural stream flow decreases. Remaining impacts to surface water quality would be similar to the results obtained under Alternative 1.

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and implementation of active treatment, along with less surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Clear Creek sub-watershed during the peak year of CBM water production is about 3 cfs (2,172 acre-feet/year). Under Alternative 2B, the resultant SAR would be adequate to meet the MRPL during high flows in April through June but not during the remainder of the irrigation season, when natural stream flow decreases. Remaining impacts to surface water quality would be similar to the results obtained under Alternative 1. Additional water would be available to support beneficial use based on the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Clear Creek sub-watershed would occur in 2006, when 1,705 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Clear Creek sub-watershed during the peak year of CBM water production is about 8 cfs (5,793 acre-feet/year). Impacts to surface water quality would be similar to those described under Alternative 1.

Crazy Woman Creek Sub-Watershed

Results of the impact analysis in the Crazy Woman Creek sub-watershed under each alternative are presented in Table 4–8. Potential impacts are discussed below.

Table 4–8 Surface Water Impact Analysis of the Crazy Woman Creek Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	2.0	1,000	10	3,200	14	2.3	1,937	28	13.8	2,545
2A	2.0	1,000	10	3,200				17	6.5	2,159
2B	2.0	1,000	10	3,200				16	5.6	2,112
3	2.0	1,000	10	3,200				19	8.0	2,240

Alternative 1

Under Alternative 1, the peak year of water production in the Crazy Woman Creek sub-watershed would occur in 2006, when 1,853 wells would be producing at an average rate of 6.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Crazy Woman Creek sub-watershed during the peak year of CBM water production is about 14 cfs (10,137 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Mean monthly EC values in Crazy Woman Creek currently exceed the MRPL, but are less than the LRPL under low-flow conditions. Mean monthly SAR values currently are about equal to the MRPL under similar flow conditions. After mixing, the resultant stream flow under low-flow conditions would nearly double from natural stream flow. The resultant EC would decrease, whereas the SAR would increase from existing conditions. The existing 7Q10 flow is calculated as zero; therefore, it is assumed that the resultant water quality under these flow conditions would be represented by the quality of CBM produced water if discharges were to occur during critical low-flow periods.

Under modeled conditions, the resultant water quality in the Crazy Woman Creek sub-watershed near Arvada, Wyoming, during all months and during 7Q10 flow conditions would not be adequate to meet the MRPL for EC, but would be adequate to meet the LRPL if it should be determined that the MRPL and LRPL criteria are protective of downstream irrigation. With the exception of during low flows in the irrigation months of August and September and during 7Q10 flow conditions, the resultant water quality in the Crazy Woman Creek sub-watershed near Arvada would be adequate to meet the LRPL for SAR. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates no effects to infiltration except during 7Q10 flow conditions. During the low monthly flow, essentially all of the CBM discharge could occur without causing potential effects to infiltration. As stated previously, it is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached under this alternative. This may help explain the situation where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Based on the higher water quality and value as a source of irrigation in the sub-watershed, current WDEQ policy would not allow any new discharge permits in this sub-watershed that would result in any decrease in baseline water quality. Because of WDEQ's policy, it is expected that water quality in Crazy Woman Creek would be preserved at near current levels.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Crazy Woman Creek sub-watershed during the peak year of CBM water production is about 3 cfs (2,172 acre-feet/year). Under Alternative 2A, the resultant water quality in June would be less than the MRPL for SAR. Remaining impacts to surface water quality would be similar to the results obtained under Alternative 1.

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and implementation of active treatment, along with reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Crazy Woman Creek sub-watershed during the peak year of CBM water production is about 2 cfs (1,448 acre-feet/year). Impacts to surface water quality would be similar to those described for Alternative 2A. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Crazy Woman Creek sub-watershed would occur in 2005, when 606 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Crazy Woman Creek sub-watershed during the peak year of CBM water production is about 5 cfs (3,620 acre-feet/year). Impacts to surface water quality would be similar to those described under Alternative 2A.

Salt Creek Sub-Watershed

Results of the impact analysis in the Salt Creek sub-watershed under each alternative are presented in Table 4–9. Potential impacts are discussed below.

Table 4–9 Surface Water Impact Analysis of the Salt Creek Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Montly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	2.0	1,000	10	3,200	27	26.1	5,750	27	25.9	5,711
2A	2.0	1,000	10	3,200				27	26.0	5,743
2B	2.0	1,000	10	3,200				27	26.1	5,750
3	2.0	1,000	10	3,200				27	26.0	5,730

Alternative 1

Under Alternative 1, the peak year of water production in the Salt Creek sub-watershed would occur in 2006, when 37 wells would be producing at an average rate of 6.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Salt Creek sub-watershed during the

65

peak year of CBM water production is about 0.2 cfs (145 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

The water quality in Salt Creek currently exceeds the MRPL and LRPL for both EC and SAR under low-flow conditions. The resultant stream flow under low monthly flow conditions would be similar to the natural stream flow. The resultant EC and SAR would decrease slightly from existing conditions.

Under modeled conditions, the resultant water quality in the Salt Creek sub-watershed near Sussex, Wyoming, during all months and during 7Q10 flow conditions would not be adequate to meet the MRPL and LRPL for both EC and SAR if it should be determined that these criteria are protective of downstream irrigation. A comparison of the resultant quality of the mixed water with the Ayers-Westcot diagram indicates no effects to infiltration under similar flow conditions. As stated previously, it is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached under this alternative. This may help explain the situation where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Alternative 2A

Under Alternative 2A, there would be no surface discharge to the Salt Creek sub-watershed. Minimal amounts of subsurface flow from infiltration impoundments would resurface in stream channels but are not likely to reach the main stem of the Salt Creek sub-watershed. Under Alternative 2A, impacts to surface water quality would be similar to the results obtained under Alternative 1.

Alternative 2B

Under Alternative 2B, there would be no untreated surface discharge to the Salt Creek sub-watershed. Minimal amounts of subsurface flow from infiltration impoundments would resurface in stream channels but are not likely to reach the main stem of the Salt Creek sub-watershed. Under Alternative 2B, impacts to surface water quality would be similar to the results obtained under Alternative 1. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Salt Creek sub-watershed would occur in 2006, when 19 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Salt Creek sub-watershed during the peak year of CBM water production is about 0.1 cfs (72 acre-feet/year). Impacts to surface water quality would be similar to those described under Alternative 1.

Wyoming/Montana Stateline Surface Water Impact Analysis

This section describes the effects from each alternative by sub-watershed.

BEST COPY AVAILABLE

66

Upper Tongue River Sub-Watershed

The surface water impact analysis of the Upper Tongue River sub-watershed incorporates current and forecast future development of CBM resources in the Montana portion of the Upper Tongue River sub-watershed. This development is likely to contribute CBM produced water flows upstream of the USGS gauging station on the Tongue River at the state line near Decker, Wyoming.

This analysis assumed that Montana's Preferred Alternative E would be selected. Montana's Alternative E emphasizes the beneficial uses of produced water from CBM wells. Alternative E could include discharges that involve both treated and untreated produced water, so long as Montana Pollutant Discharge Elimination System (MPDES) permit requirements are met. This impact analysis includes existing discharges of CBM produced water in the Upper Tongue River sub-watershed from Montana's CX Ranch field. Montana's existing permitted discharge incorporated in this modeling effort includes produced water from 120 wells at a discharge rate of 50 percent of the permitted maximum discharge (Langhus 2002).

Results of the impact analysis in the Upper Tongue River sub-watershed under each alternative are presented in Table 4–10. Potential impacts are discussed below.

Table 4–10 Surface Water Impact Analysis of the Upper Tongue River Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	0.5	500	10	2,500	178	0.9	731	189	3.1	826
2A	0.5	500	10	2,500				183	1.9	776
2B	0.5	500	10	2,500				183	1.8	770
3	0.5	500	10	2,500				188	2.9	82[illegible]

Alternative 1

Under Alternative 1, the peak year of water production in the Upper Tongue River sub-watershed would occur in 2006, when 1,948 wells would be producing at an average rate of 6.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Tongue River sub-watershed during the peak year of CBM water production is about 11 cfs (7,965 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

The Tongue River is an important source of irrigation water in and downstream of the Project Area. With the exception of the highest flow months of May and June, the water quality in the Tongue River currently exceeds the MRPL for EC and SAR. Thus, any additional discharge that would reach the main stem would likely cause further degradation in terms of suitability for irrigation if the states and EPA conclude that the MRPL is protective of irrigation. The water quality in

67

the Tongue River currently is less than the LRPL for both EC and SAR. After mixing, the resultant flow under low monthly flow conditions would increase slightly. The resultant EC and SAR would increase from existing conditions.

Under modeled conditions, the resultant water quality in the Upper Tongue River sub-watershed would not meet the MRPL for both EC and SAR except during high flows in May and June. The resultant water quality would be adequate to meet the LRPL for both EC and SAR under mean monthly flow during all months of the year and during 7Q10 flow conditions. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates that some reduction in infiltration would be likely during some months of the irrigation season. However, essentially all of the CBM discharge could occur without causing potential effects to infiltration during the low monthly flow.

Based on modeled results, under certain flow conditions impacts to the suitability for irrigation of the Upper Tongue River sub-watershed from CBM development in Wyoming and Montana under Alternative 1 would be expected to occur at the Decker, Wyoming, station using the MRPL and LRPL criteria, if the states and EPA conclude that the proposed limits would be protective of irrigation. However, surface discharge to the Upper Tongue River sub-watershed from Wyoming CBM development would be controlled by WDEQ's interim "no new discharge" policy; thus, WDEQ would not authorize the percentage of untreated surface discharge to the Upper Tongue River sub-watershed under Alternative 1 unless the quality of the discharged water was at or near the existing level in the Tongue River. Potential impacts from Montana's existing CBM discharges from the CX Ranch field to the Upper Tongue River sub-watershed would be controlled by the MPDES permit. Therefore, impacts to water quality would be more likely to result from CBM produced waters that resurface from infiltration impoundments or from migration of salts beneath LAD systems than from surface discharge. Impacts to water quality from CBM development in Wyoming to downstream uses on the Northern Cheyenne Reservation would be limited by the state's discharge policy.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Tongue River sub-watershed during the peak year of CBM water production is about 5 cfs (3,620 acre-feet/year). Changes in low monthly flows would be similar to Alternative 1. The resultant stream water quality under low-flow conditions would increase the EC and SAR from existing conditions, although less than under Alternative 1. The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Figures 4–31 and 4–32 illustrate the months during which the year when the existing water quality and resultant quality of mixed water under mean monthly flow and 7Q10 flow conditions would exceed the MRPL and LRPL considered for water quality in the Upper Tongue River sub-watershed.

68

Under Alternative 2A, the resultant EC under mean monthly and 7Q10 flow conditions is greater than the MRPL except during the highest flow months of May and June when CBM produced water discharges from both states are mixed. The resultant EC is less than the LRPL under similar flow conditions.

Under Alternative 2A, the resultant SAR under mean monthly and 7Q10 flow conditions is greater than the MRPL except during the highest flow months of May and June when discharges of CBM produced water from both states are mixed. The resultant SAR is less than the LRPL under similar flow conditions.

Figure 4–33 illustrates the relationship between EC and SAR in the Tongue River before and after mixing with discharges of CBM produced water under Wyoming's Alternative 2A and Montana's Alternative E. Figure 4–34 compares existing stream water and quality of mixed water in terms of suitability for irrigation and especially for impacts on soils irrigated. Below and to the right of the irrigation threshold line in Figure 4–33, water quality would be expected to cause "no reduction in the rate of infiltration" because soils would be dispersed by SAR (Ayers and Westcot 1985). To the left and above the line, water would be likely to cause "slight to moderate reduction in the rate of infiltration" (Ayers and Westcot 1985). Although dispersion and consequent reduction in the rate of infiltration depend somewhat on clay content, the threshold line shown in Figure 4–33 is used as an indicator of suitability.

Under Alternative 2A, a comparison of the resultant mixed water quality with the Ayers-Westcot diagram in Figure 4–33 indicates that there is not likely to be a reduction in infiltration under mean monthly or 7Q10 flow conditions.

Figure 4–34 illustrates the relationship between EC and SAR in the Upper Tongue River sub-watershed after the water has mixed with varying proportions of discharges from CBM produced water under various streamflow conditions.

Under Alternative 2A, essentially all of the CBM discharge to the Upper Tongue River sub-watershed from both states could occur during the low monthly flow and during 7Q10 flow conditions without causing effects to infiltration. As stated previously, it is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached under this alternative. This may help explain the situation where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Based on modeled results, impacts to the suitability for irrigation of the Tongue River from CBM development in Wyoming and Montana under Alternative 2A would not be expected to occur.

69

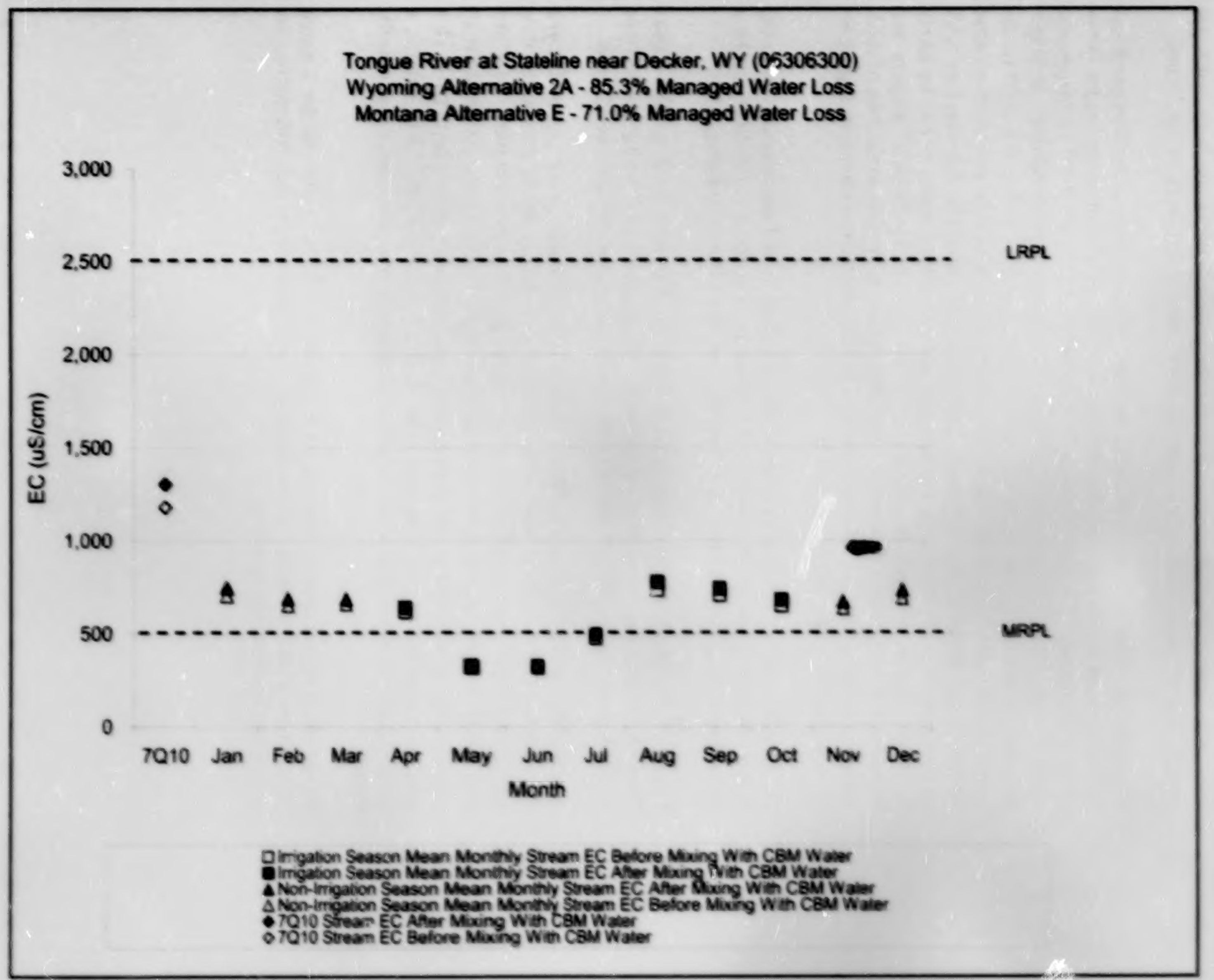


Figure 4–31 Stream EC Before and After Mixing – Upper Tongue River Sub-Watershed

70

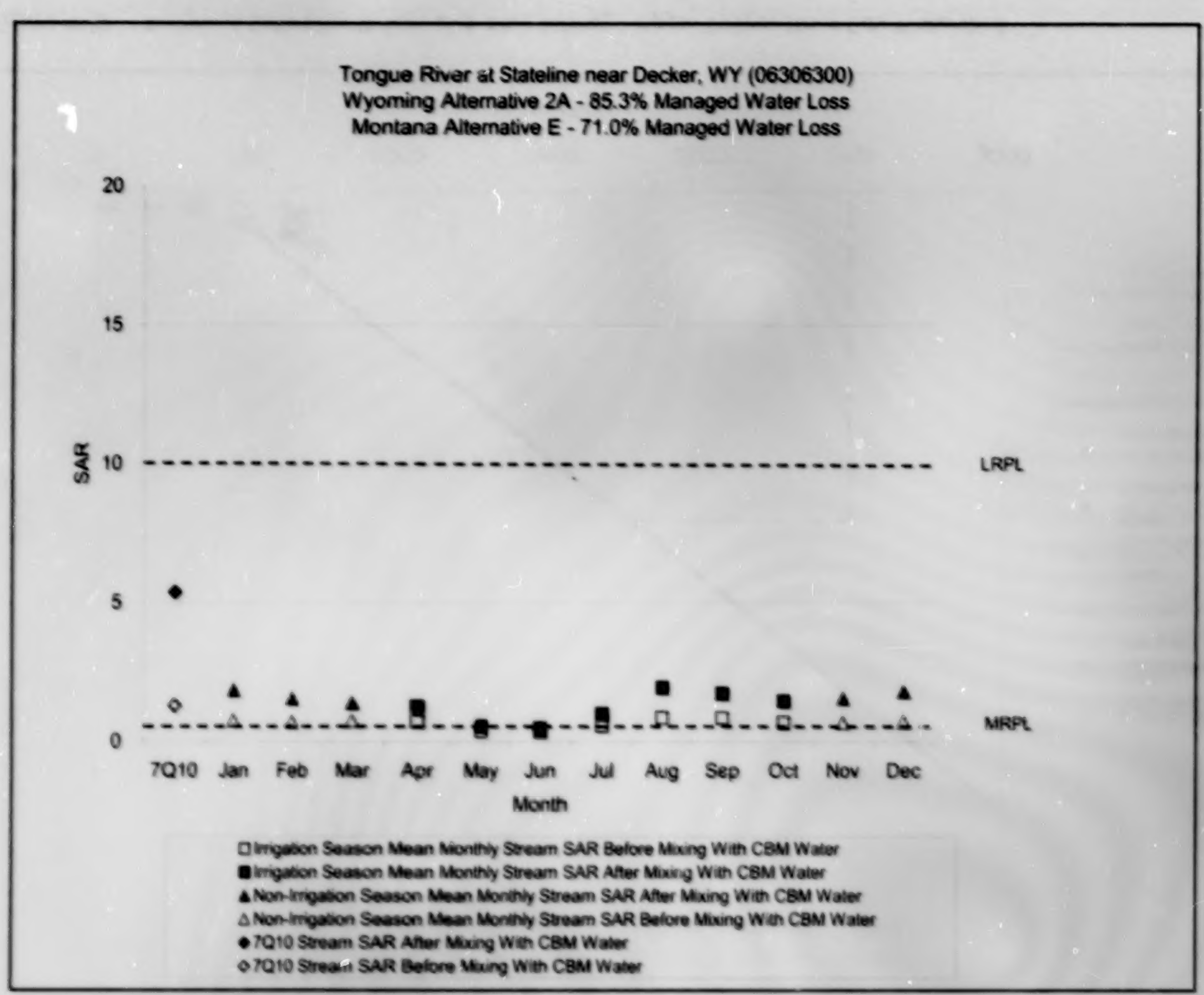


Figure 4-32 Stream SAR Before and After Mixing – Upper Tongue River Sub-Watershed

BEST COPY AVAILABLE

71

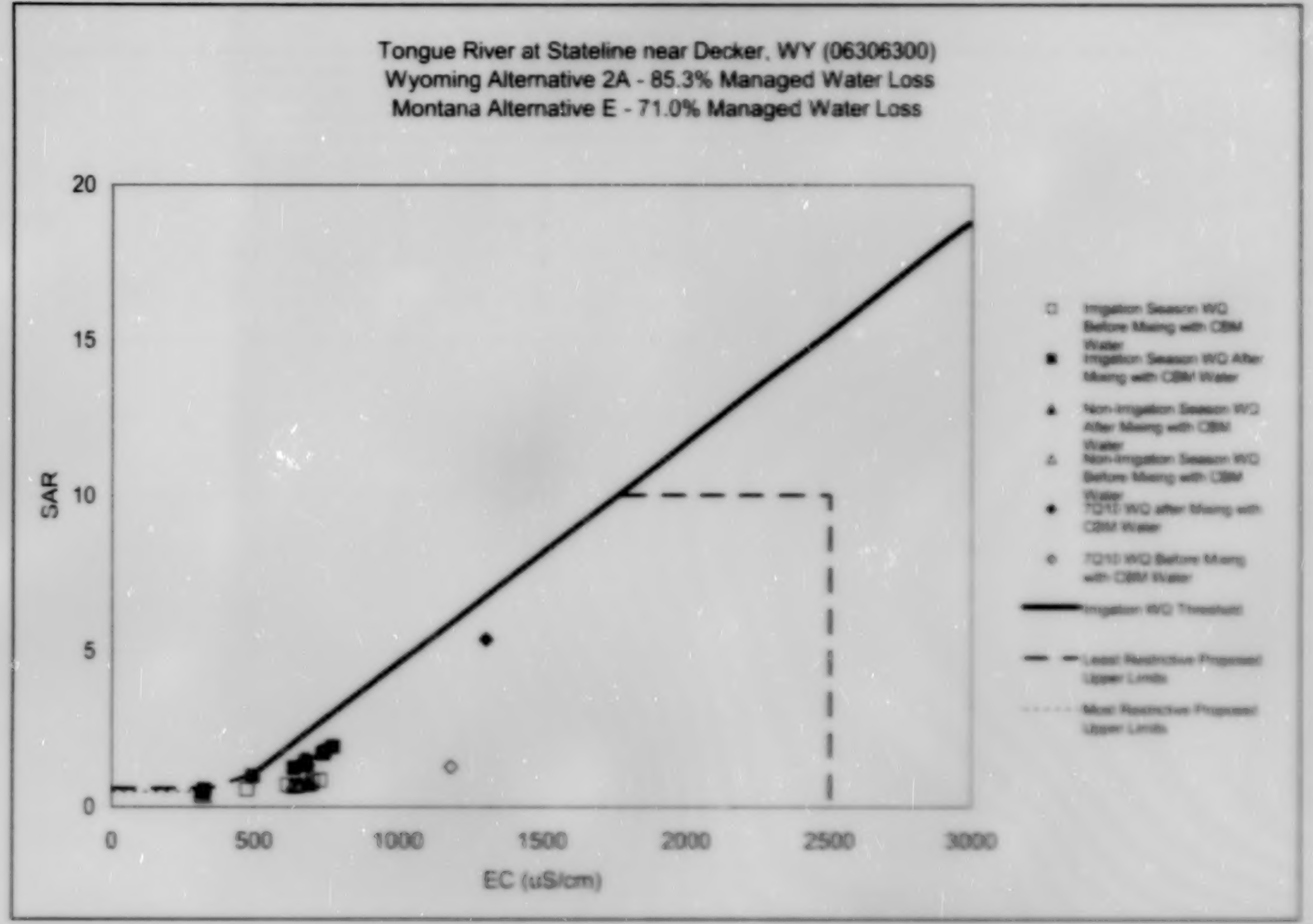


Figure 4-33 **Irrigation Suitability Before and After Mixing – Upper Tongue River Sub-Watershed**

72

BLANK PAGE

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in LAD for water handling and implementation of active treatment. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Tongue River sub-watershed during the peak year of CBM water production is about 4 cfs (2,896 acre-feet/year). Impacts to surface water quality in the Upper Tongue River sub-watershed would be less than are described under Alternative 1, and similar to Alternative 2A. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Upper Tongue River sub-watershed would occur in 2006, when 1,786 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Tongue River sub-watershed during the peak year of CBM water production is about 10 cfs (7,241 acre-feet/year). Impacts to surface water quality in the Upper Tongue River sub-watershed would be similar to those described under Alternative 1.

Middle Powder River Sub-Watershed

The surface water impact analysis of the Middle Powder River sub-watershed incorporates the cumulative discharges of CBM produced water from the Clear Creek, Crazy Woman Creek, Salt Creek, and Upper Powder River sub-watersheds. The analysis also includes the addition of current and future forecast development of CBM in the Montana portion of the Middle Powder River sub-watershed that would be likely to contribute flows of CBM produced water upstream of the USGS gauging station on the Powder River at Moorhead, Montana.

This analysis assumed that Montana's Preferred Alternative E would be selected. Under Alternative E, Montana would not allow untreated surface discharge from CBM wells to the Middle Powder River sub-watershed (in other words, managed water losses would equal 100 percent) if Wyoming were to implement Alternative 1. Montana would, however, allow unlimited (100 percent) surface discharge, assuming MPDES permit requirements were met, if Wyoming were to implement any of Alternatives 2A, 2B, or 3. Under the latter scenario, Montana's contribution to flows in the Powder River at the Moorhead, Montana gauging [illegible] would include discharges from 500 CBM wells. Of course, site-specific [illegible] and the actual surface water standards adopted by the MBER will be [illegible] important factors in determining the actual water management practices [illegible] the Montana portion of the PRB. The MDEQ cannot allow discharges of CBM water to impact surface water conditions in excess of prevailing regulations and standards. CBM producers in the Wyoming portion of this watershed will be held to the same standards if the Montana standards are approved by the EPA and given CWA standing. Results of the impact analysis in the Middle Powder river sub-watershed under each alternative are presented in Table 4-11. Potential water quality impacts are discussed below.

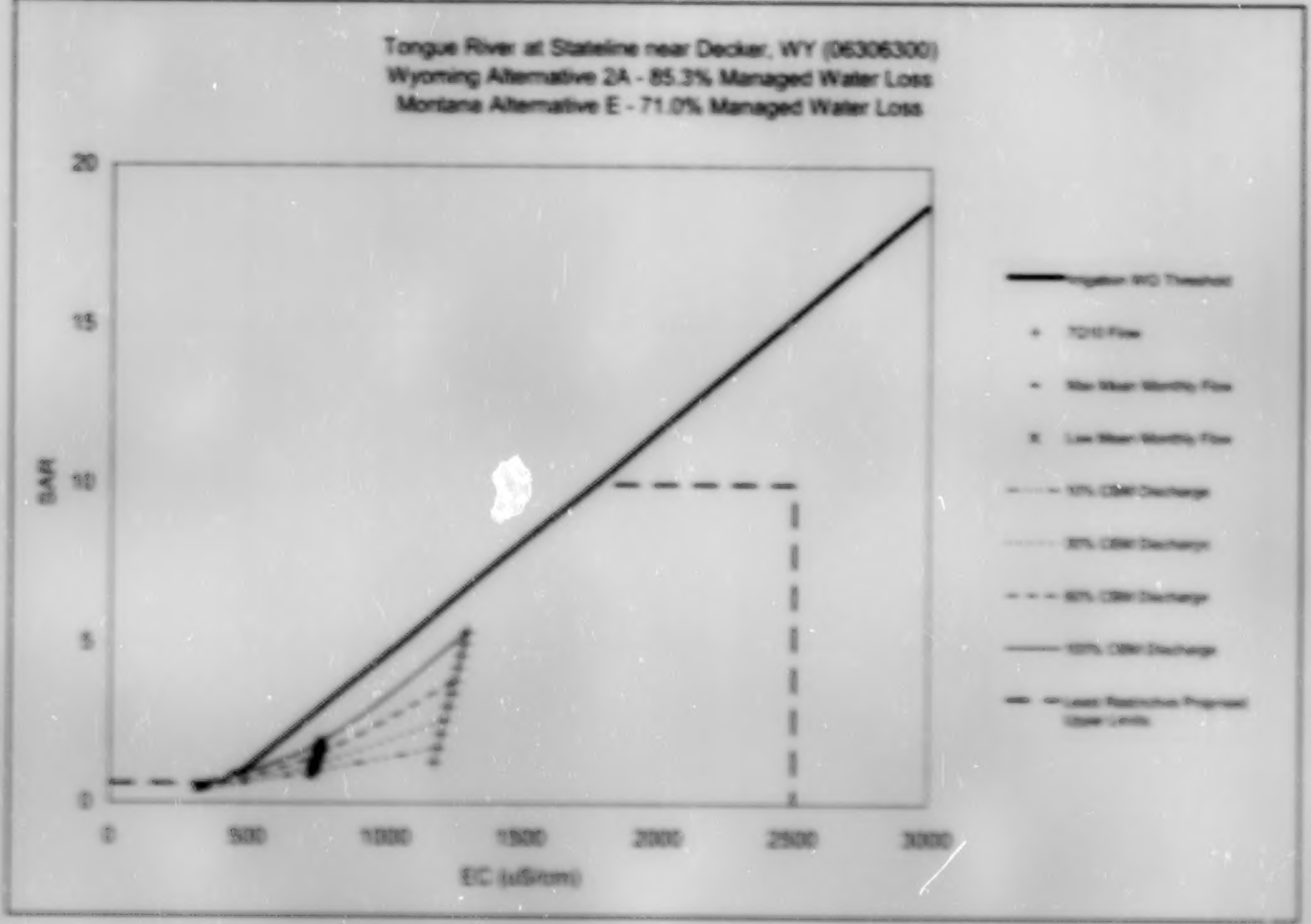


Figure 4-34 Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge - Upper Tongue River Sub-Watershed

71

BLANK PAGE

Table 4–11 Surface Water Impact Analysis of the Middle Powder River Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	2.0	1,000	10	3,200	145	4.6	2,154	312	13.8	2,270
2A	2.0	1,000	10	3,200				230	11.6	2,253
2B	2.0	1,000	10	3,200				223	11.2	2,249
3	2.0	1,000	10	3,200				218	11.3	2,270

Alternative 1

Under Alternative 1, the peak year of water production in the Middle Powder River sub-watershed would occur in Year 2005, when 21,047 wells would be producing at an average rate of 6.2 gpm per well. The peak year of water production in the Salt Creek, Clear Creek, Crazy Woman Creek, and Upper Powder River sub-watersheds would occur in 2006, however, for the purpose of this analysis, the number of wells producing in those watersheds during 2006 was used for the cumulative analysis in the Middle Powder River sub-watershed for 2005 to predict the impacts during the "peak year." Under modeled conditions, the amount of produced water assumed to reach the main stem of the Middle Powder River sub-watershed during the peak year of CBM water production is about 167 cfs (120,920 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Mean monthly EC and SAR values in the Middle Powder River currently exceed the MRPL for both constituents under low mean monthly and 7Q10 flow conditions. With the exception of the EC under 7Q10 flow conditions, the water quality currently is less than the LRPL for both EC and SAR under similar flow conditions. After mixing, natural stream flow would increase by approximately twofold during low-flow conditions. The resultant EC and SAR would increase from existing conditions.

Under modeled conditions, the resultant water quality in the Middle Powder River sub-watershed would not meet the MRPL for both EC and SAR during all months and during 7Q10 flow conditions. The resultant water quality would be adequate to meet the LRPL for EC during all months of the year. It would not, however, be adequate to meet the LRPL for SAR during the lowest flow months, which includes the irrigation season from August through October. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates that there would be no reduction in infiltration except during 7Q10 flow conditions. During the low monthly flow, essentially all of the CBM discharge could occur without causing potential effects to infiltration.

Based on modeled results, under certain flow conditions, impacts to the suitability for irrigation of the Middle Powder River from CBM development in Wyo-

ming and Montana would occur at the Moorhead, Montana, station using the MRPL and LRPL criteria, if the states and the EPA conclude that the proposed limits would be protective of irrigation.

Modeling indicates that the suitability of the Powder River for irrigation may be compromised by the surface discharge of CBM produced water during maximum development of CBM in both states. Enhanced monitoring of CBM discharges and an evaluation of downstream irrigation practices would be necessary to determine if there would be a measurable decrease in crop production, however. State permitting procedures in Wyoming require CBM operators to include an irrigation use protection plan with the NPDES permit application. This plan specifies necessary measures to prevent violating the narrative standards for the protection of irrigated agriculture in the Powder River drainage. Mitigation measures would be implemented based on the site-specific analysis of existing irrigation practices. CBM operators could be required to increase the amount of storage of CBM water during the irrigation months to meet the needs of downstream irrigators and proceed with more surface discharge during the non-irrigation months. As the state develops a better understanding of the effects of CBM discharges through the enhanced monitoring required by the MOC, the permitting approach can be adjusted to allow more or less discharges to the Powder River drainage. Thus, water quality standards and agreements with bordering states can be met.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Middle Powder River sub-watershed during the peak year of CBM water production from development in both states is about 86 cfs (62,270 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

After mixing, natural stream flows would almost double under low-flow conditions. The resultant EC and SAR would increase from existing conditions, although the increases would be less than under Alternative 1.

Figures 4–35 and 4–36 are used to illustrate the months during the year that the existing water quality and resultant quality of mixed water under mean monthly flow and 7Q10 flow conditions would exceed the MRPL and LRPL considered for water quality in the Middle Powder River sub-watershed.

Under Alternative 2A, when CBM produced water discharges from both states are mixed, the resultant EC under mean monthly and 7Q10 flow conditions is greater than the MRPL during all months of the year. The resultant EC is less than the LRPL under similar flow conditions.

Under Alternative 2A, the resultant SAR under mean monthly and 7Q10 flow conditions is greater than the MRPL during all months of the year when discharges of CBM produced water from both states are mixed. The resultant SAR would not be adequate to meet the LRPL during the lowest flow months, which includes the irrigation months of August through October, or during 7Q10 flow conditions.

Figure 4–37 illustrates the suitability for irrigation of the Powder River before and after it mixes with discharges of CBM produced water.

Under Alternative 2A, a comparison of the resultant quality of mixed water with the Ayers-Westcot diagram in Figure 4–37 indicates that there is not likely to be a reduction in infiltration except under 7Q10 flow conditions.

Figure 4–38 illustrates the relationship between EC and SAR in the Middle Powder River sub-watershed after it mixes with varying proportions of discharges of CBM produced water under various streamflow conditions.

Under Alternative 2A, essentially all of the CBM discharge to the Middle Powder River sub-watershed from both states could occur without causing effects to infiltration, with the exception of 7Q10 flow conditions. As stated previously, it is important to be mindful of an upper bound on the Ayers-Westcot relationship in reviewing the conclusions reached under this alternative. This may help explain the situation where the MRPL (or perhaps, the LRPL) shows a potential effect, where the Ayers-Westcot diagram indicates no reduction in infiltration.

Based on modeled results, under certain flow conditions, impacts to irrigated agriculture in the Powder River sub-watershed from CBM development in Wyoming and Montana under Alternative 2A may occur. Although the resultant impacts fall outside the boundaries of the LRPL during some months, BLM recognizes the uncertainty concerning the determination of water quality standards for EC and SAR. If a standard at the low end of the range of proposed values is selected, additional mitigation may be necessary for CBM discharges to this sub-watershed to occur. Potential mitigation measures that could be implemented in order to meet the ultimate regulatory standards for EC and SAR once those standards have been identified include CBM produced water storage during the irrigation months and surface discharge during the non-irrigation months. In addition, discharge permits issued by the WDEQ would be the mechanism that would identify the appropriate mix of water handling methods to be employed to meet the standards. Producers also may decide to limit development in the Middle Powder River sub-watershed to meet permit requirements rather than utilizing other water management practices (infiltration, treatment, LAD). As a result, even though the model predicts impacts, ultimately those predicted impacts to the irrigation suitability of the Powder River from CBM development in Wyoming and Montana under Alternative 2A may not occur.

77

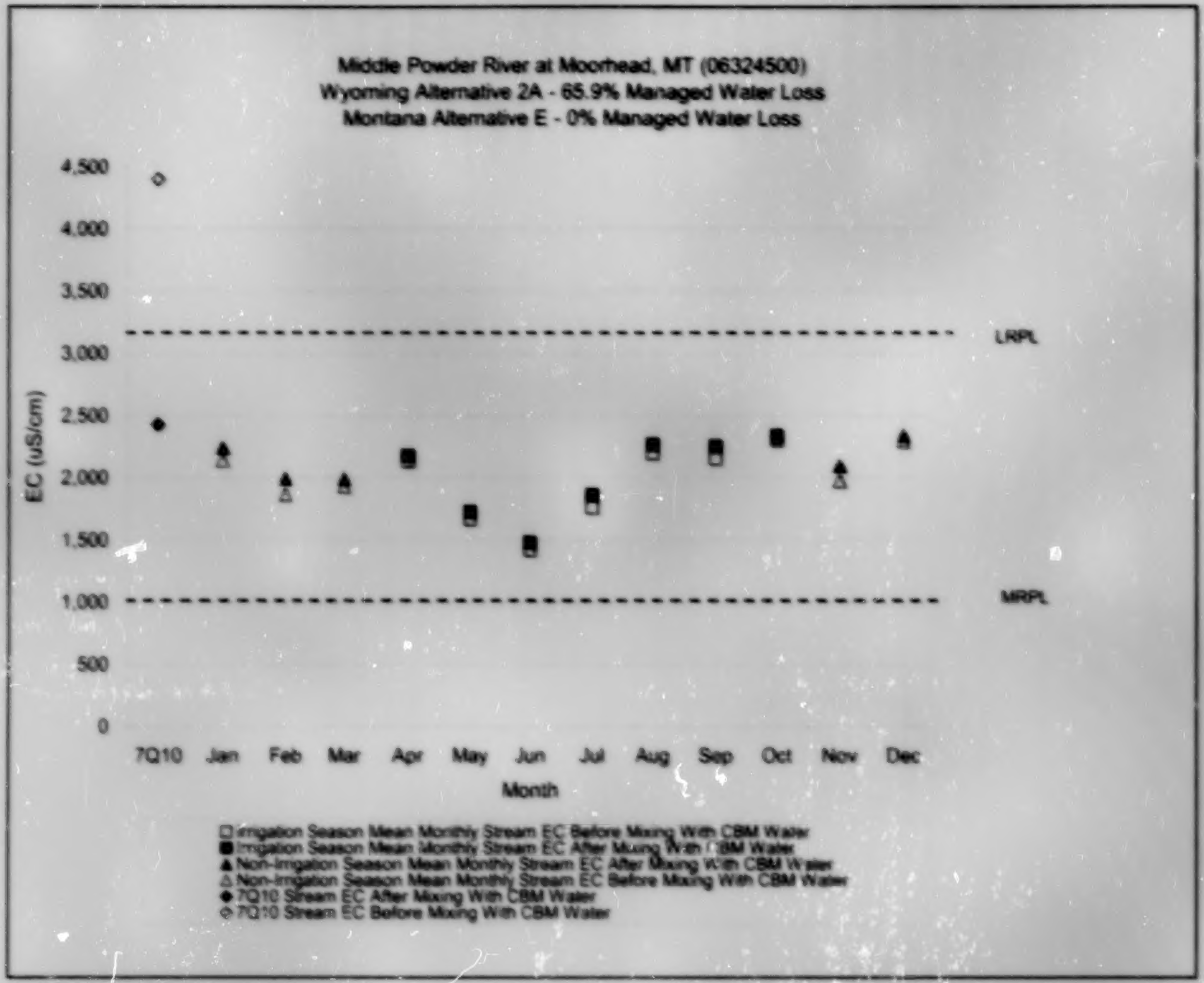


Figure 4-35 Stream EC Before and After Mixing – Middle Powder River Sub-Watershed

79

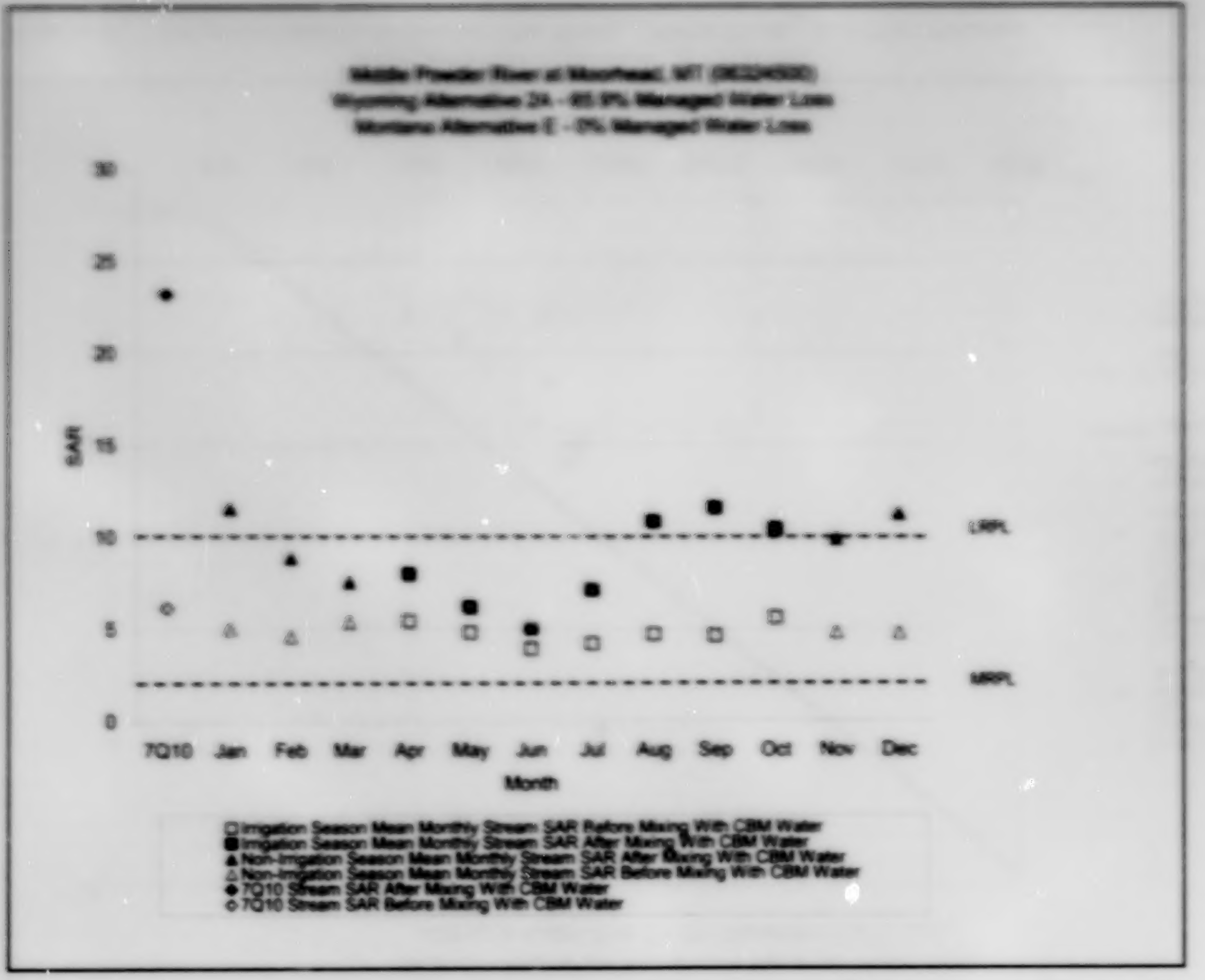


Figure 4–36 Stream SAR Before and After Mixing – Middle Powder River Sub-Watershed

BEST COPY AVAILABLE

79

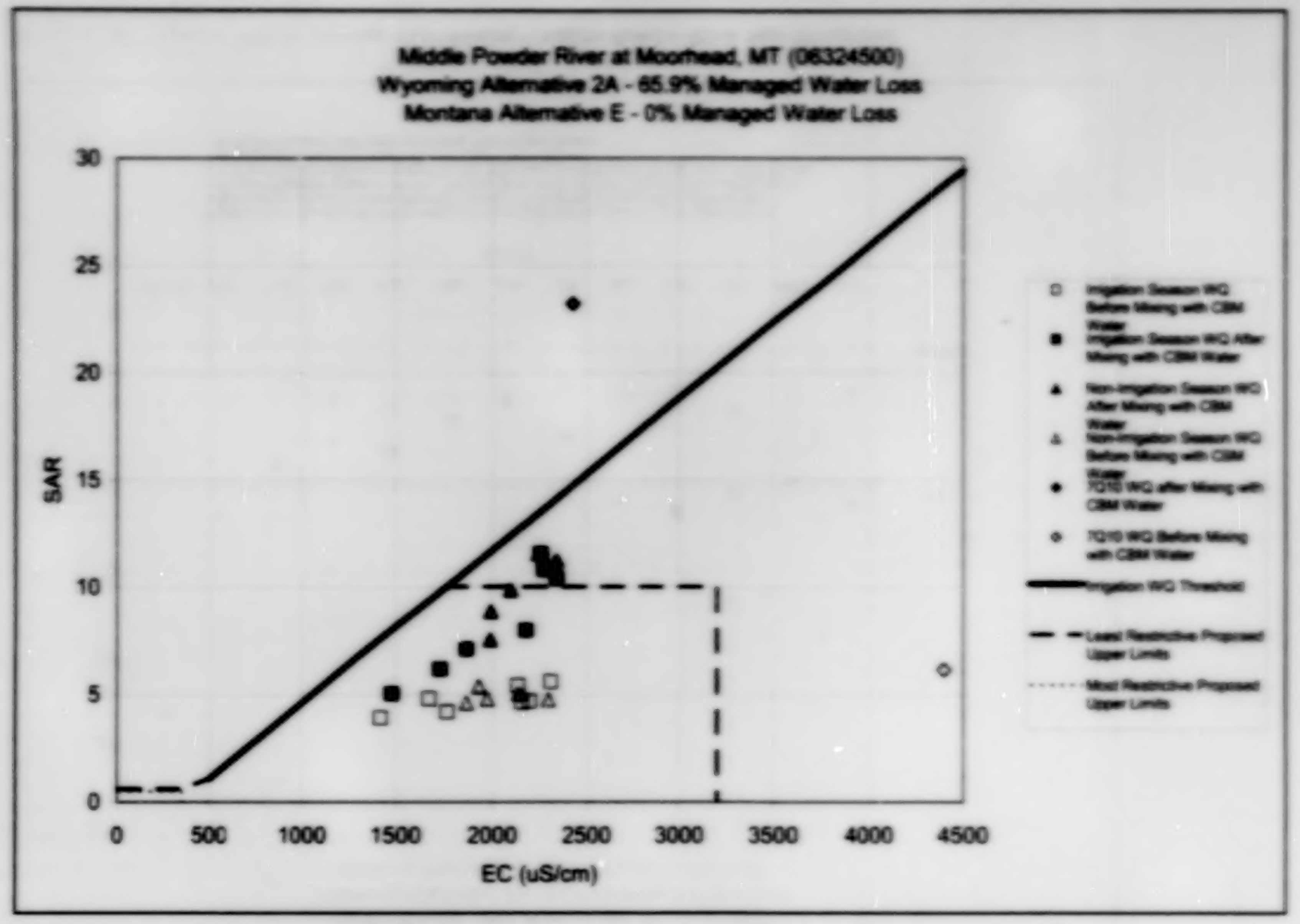


Figure 4-37 Irrigation Suitability Before and After Mixing – Middle Powder River Sub-Watershed

BEST COPY AVAILABLE

80

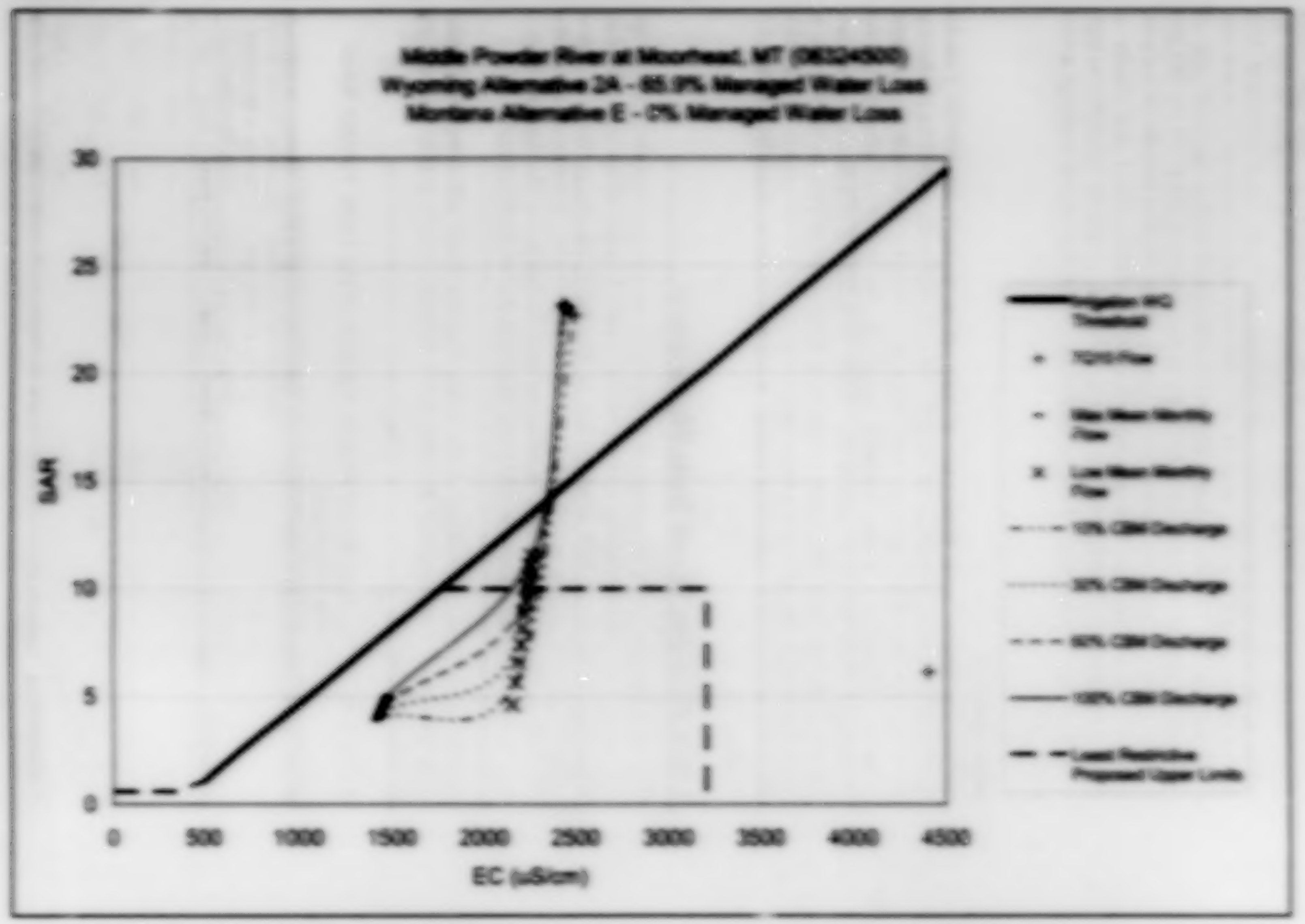


Figure 4-38 Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Middle Powder River Sub-Watershed

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and implementation of active treatment. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Middle Powder River sub-watershed during the peak year of CBM water production from development in both states is about 79 cfs (57,200 acre-feet/year). Impacts to surface water quality in the Middle Powder River sub-watershed would be less than are described under Alternative 1 and similar to those described for Alternative 2A. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Middle Powder River sub-watershed would occur in 2005, when 8,469 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Middle Powder River sub-watershed during the peak year of CBM water production from development in both states is about 74 cfs (53,581 acre-feet/year). Impacts to surface water quality in the Middle Powder River sub-watershed would be similar to those described under Alternative 1.

Little Powder River Sub-Watershed

The development of CBM resources in Montana would not contribute flows upstream of the USGS gauging station on the Little Powder River near Weston, Wyoming. However, CBM development in Wyoming has the potential to cause impacts to water quality in this drainage. As a result, future forecast development of CBM resources downstream in Montana may be limited in the amount of surface discharge to this drainage under the Montana preferred alternative.

Results of the impact analysis in the Little Powder River sub-watershed under each alternative are presented in Table 4–12. Potential water quality impacts are discussed below.

Table 4–12 Surface Water Impact Analysis of the Little Powder River Sub-Watershed

Alternative	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
1	3.0	1,000	10	3,000	3	6.9	3,300	23	10.6	1,519
2A	3.0	1,000	10	3,000				16	10.4	1,606
2B	3.0	1,000	10	3,000				15	10.4	1,625
3	3.0	1,000	10	3,000				18	10.5	1,564

Alternative 1

Under Alternative 1, the peak year of water production in the Little Powder River sub-watershed would occur in 2005, when 2,543 wells would be producing at an average rate of 6.2 gpm per well. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Little Powder River sub-watershed during the peak year of CBM water production is about 19 cfs (13,757 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction.

Mean monthly EC and SAR values in the Little Powder River currently exceed the MRPL for both constituents under low mean monthly and 7Q10 flow conditions. Mean EC and SAR values currently are less than the LRPL for both constituents during low-flow conditions. After mixing, the resultant stream flow under low-flow conditions would increase substantially. The resultant EC would decrease, whereas the SAR would increase from existing conditions. The existing 7Q10 flow is calculated as zero, so that the resultant water quality under these flow conditions would be represented by the quality of CBM produced water if discharges were to occur during critical low-flow periods.

Under modeled conditions, the resultant water quality in the Little Powder River sub-watershed during all months and during 7Q10 flow conditions would not meet the MRPL for both EC and SAR. The resultant water quality would be adequate to meet the LRPL for EC during all months of the year. It would not, however, be adequate to meet the LRPL for SAR during the lowest flow months, which includes the irrigation season of August and September. A comparison of the resultant quality of mixed water with the *Ayers-Westcot* diagram indicates that there would be some reduction in infiltration during some months of the irrigation season and during 7Q10 flow conditions. During the low monthly flow, about 40 percent of the CBM discharge could occur without causing potential effects to infiltration.

Based on modeled results, under certain flow conditions, impacts to the suitability for irrigation of the Little Powder River sub-watershed from CBM development in Wyoming would occur at the Weston, Wyoming station using the Ayers-Westcot diagram and MRPL and LRPL criteria for EC and SAR if the states and the EPA conclude that the proposed limit would be protective of irrigation.

Modeling indicates that the suitability of the Little Powder River for irrigation may be compromised by the surface discharge of CBM produced water during maximum CBM development in both states. However, enhanced monitoring of CBM discharges and an evaluation of downstream irrigation practices would be necessary to determine if there would be a measurable decrease in crop production. State permitting procedures in Wyoming require CBM operators to include an irrigation use protection plan with the NPDES permit application. This plan specifies necessary measures to prevent violating the narrative standards for the protection of irrigated agriculture in the Powder River drainage. Mitigation measures would be implemented based on the site-specific analysis of existing irrigation practices. CBM operators could be required to increase the amount of storage of CBM water during the irrigation months to meet the needs of downstream irrigators and proceed with more surface discharge during the non-irrigation months. As the state develops a better understanding of the effects of

CBM discharges through the enhanced monitoring required by the MOC, the permitting approach can be adjusted to allow more or less discharges to the Little Powder River drainage. Thus, water quality standards and agreements with bordering states can be met.

Alternative 2A

Under Alternative 2A, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and reduced surface discharge. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Little Powder River sub-watershed during the peak year of CBM water production is about 13 cfs (9,143 acre-feet/year). The volume of water production would be less in other than the peak year, and modeled impacts would correspond to this reduction. The resultant water quality in streams would decrease in EC and increase in SAR from existing conditions under both low monthly and mean monthly flow conditions, although the increases would be less than under Alternative 1.

Figures 4–39 and 4–40 illustrate the months during the year when the existing water quality and resultant quality of mixed water under mean monthly flow and 7Q10 flow conditions would exceed the MRPL and LRPL considered for water quality in the Little Powder River sub-watershed.

Under Alternative 2A, the resultant EC under mean monthly flow conditions is greater than the MRPL during all months of the year. The resultant EC is less than the LRPL under both mean monthly and 7Q10 flow conditions.

Under Alternative 2A, the resultant SAR under mean monthly and 7Q10 flow conditions is greater than the MRPL during all months of the year. The resultant SAR is less than the LRPL, except potentially during the lowest flow months and during 7Q10 flow conditions.

Figure 4–41 illustrates the irrigation suitability of the Little Powder River before and after it mixes with discharges of CBM produced water under Wyoming's Alternative 2A.

Under Alternative 2A, a comparison of the resultant quality of mixed water with the Ayers-Westcot diagram in Figure 4–41 indicates that there would be some reduction in infiltration during some months of the irrigation season and under 7Q10 flow conditions.

Figure 4–42 illustrates the relationship between EC and SAR in the Little Powder River sub-watershed after the water mixes with varying proportions of discharges of CBM produced water under various streamflow conditions.

Under Alternative 2A, about 50 percent of the CBM discharge could occur during the low monthly flow without causing effects to infiltration.

BLANK PAGE

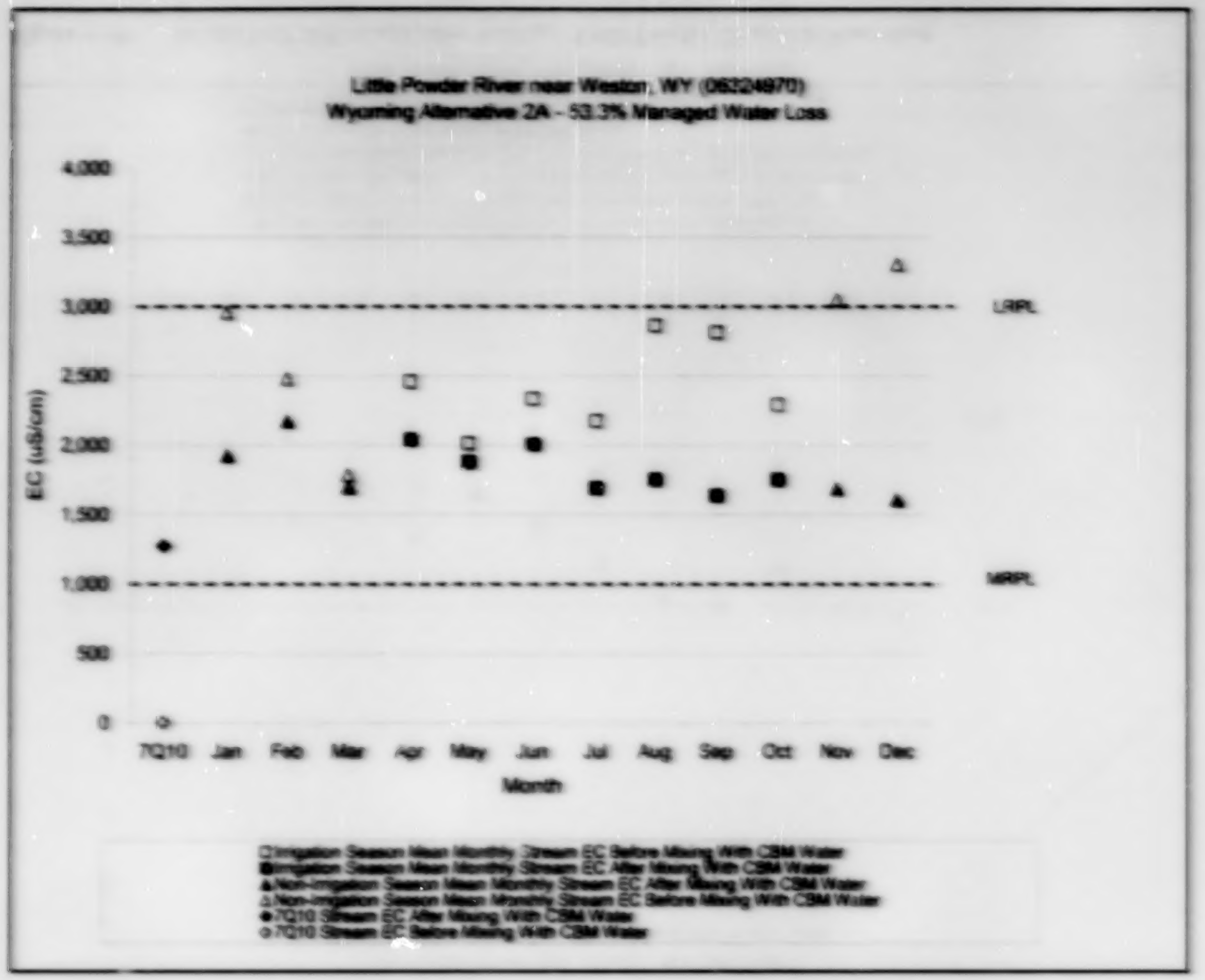


Figure 4-39 Stream EC Before and After Mixing – Little Powder River Sub-Watershed

BEST COPY AVAILABLE

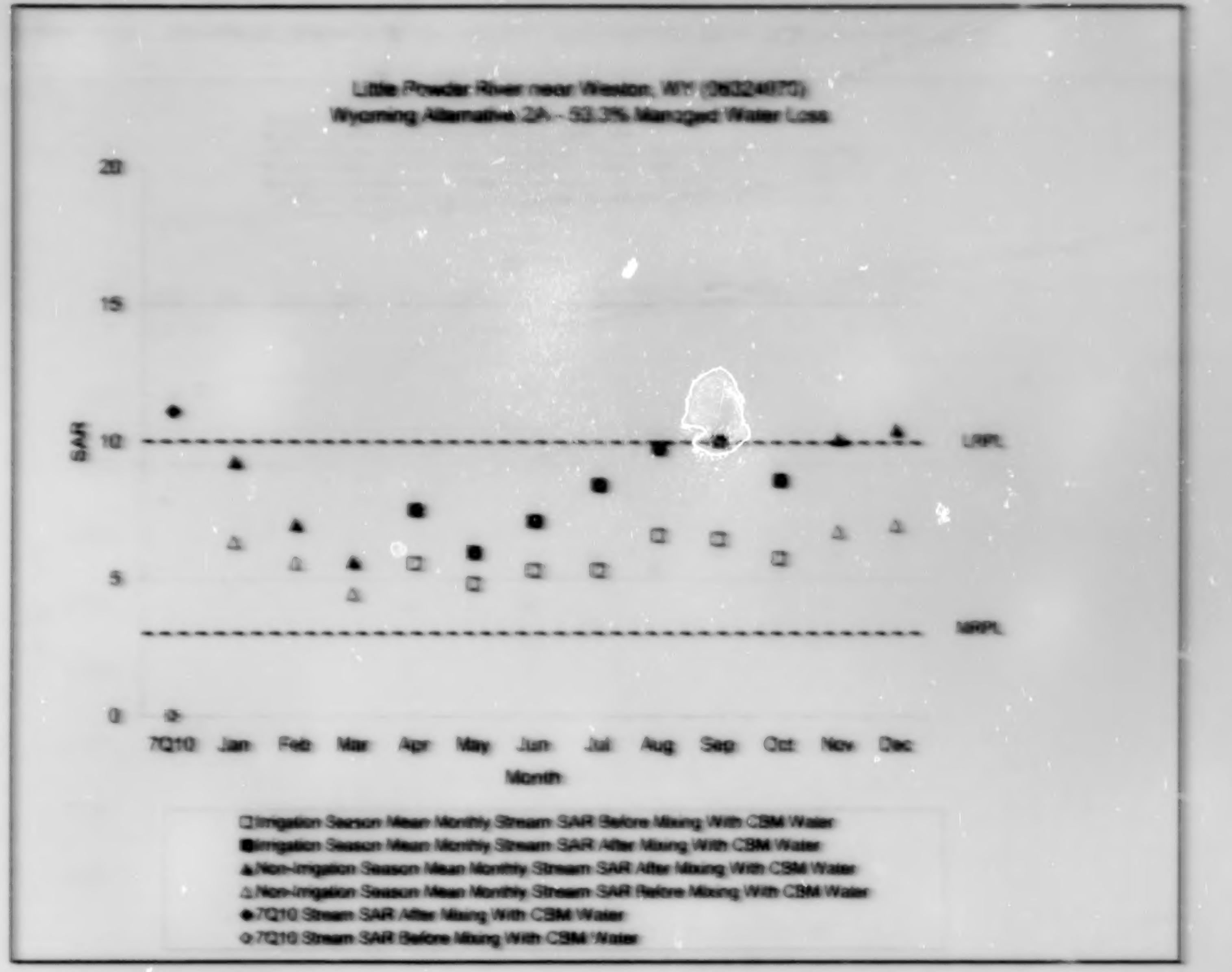


Figure 4-40 Stream SAR Before and After Mixing – Little Powder River Sub-Watershed

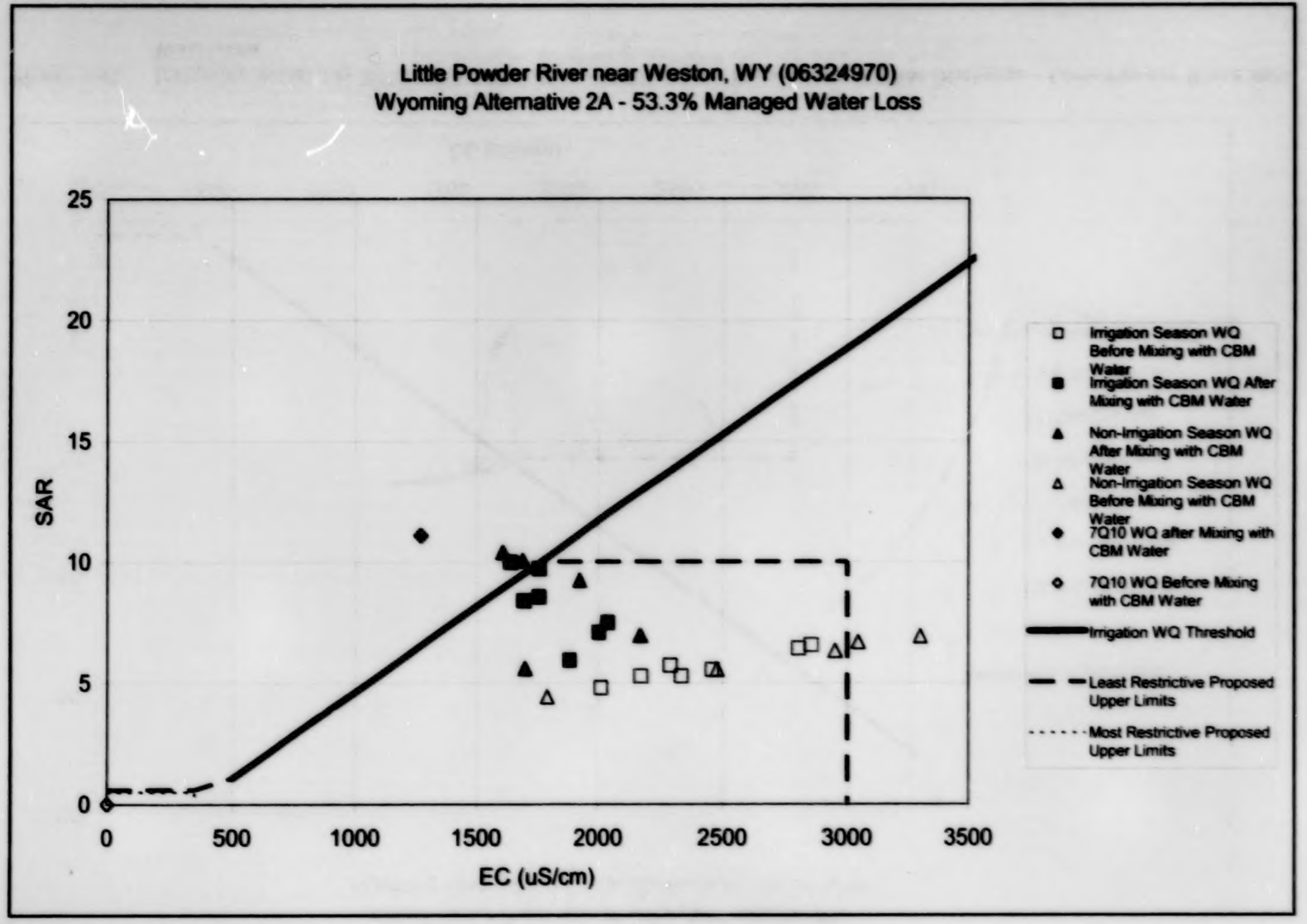


Figure 4–41 Irrigation Suitability Before and After Mixing – Little Powder River Sub-Watershed

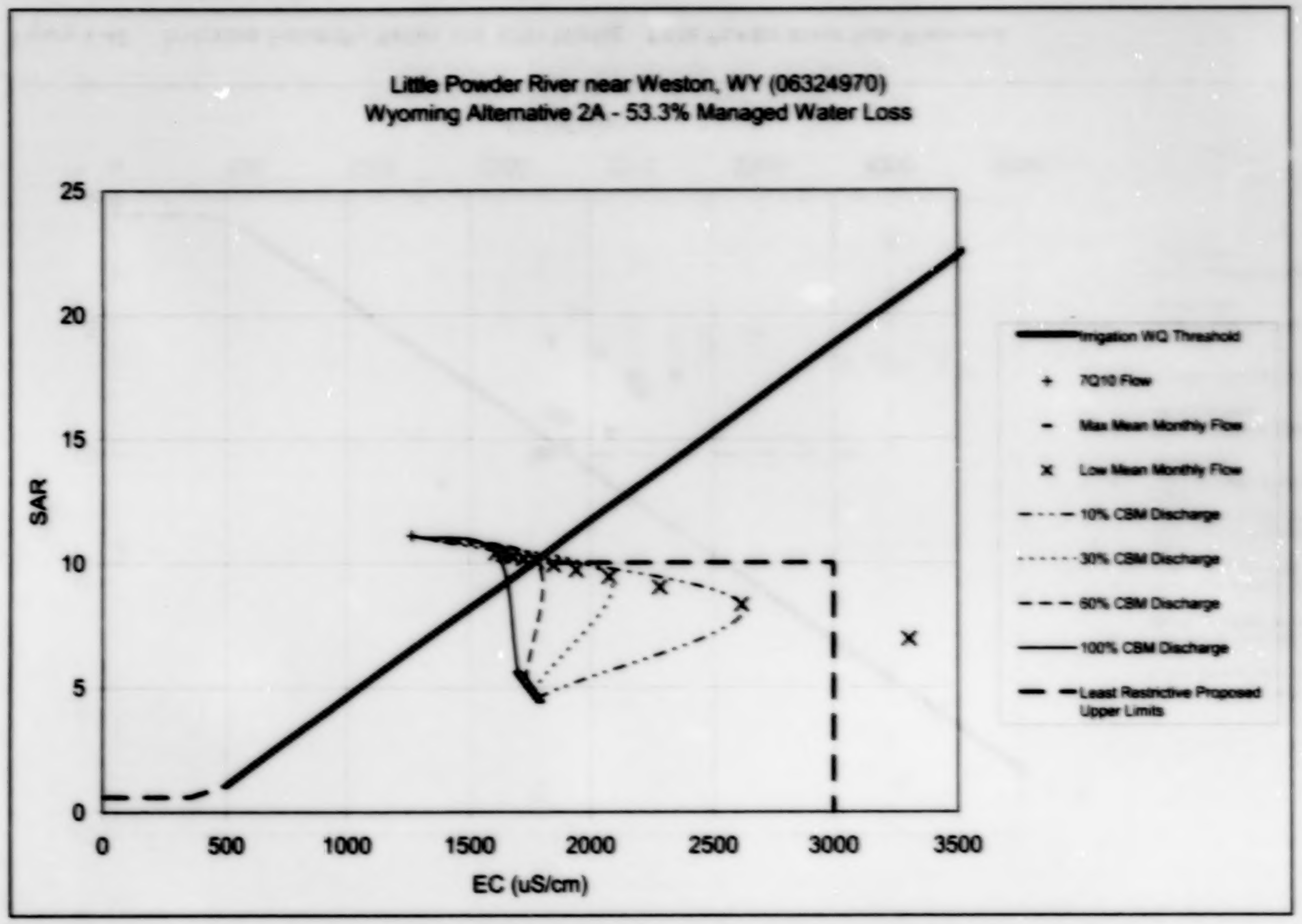


Figure 4–42 Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Little Powder River Sub-Watershed

BEST COPY AVAILABLE

BLANK PAGE

Based on modeled results, under certain flow conditions, impacts to the suitability for irrigation of the Little Powder River from CBM development may occur. However, as noted previously, samples collected since the onset of CBM production in the Upper Belle Fourche River and Little Powder River sub-watersheds have not detected changes in ambient stream water quality which were predicted by the mass balance model, and actual impacts may be less then the mass balance model predicts. The magnitude of the model results can not be verified based upon actual measured water quality data. Adequate protection of existing uses and water quality standards can only be accomplished through direct monitoring of stream water quality to measure the effects of CBM discharge. In addition, discharge permits issued by the WDEQ would be the mechanism that would identify the appropriate mix of water handling methods to be employed to meet the standards. Producers also may decide to limit development in the Little Powder River sub-watershed to meet permit requirements rather than utilizing other water management practices (infiltration, treatment, LAD). As a result, even though the model predicts impacts, ultimately those predicted impacts to the irrigation suitability of the Little Powder River from CBM development in Wyoming under Alternative 2A may not occur.

Alternative 2B

Under Alternative 2B, the peak year of water production and the water produced from CBM wells would be the same as under Alternative 1. Managed water losses would be greater than under Alternative 1, primarily because of the increase in infiltration impoundments and implementation of active treatment. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Little Powder River sub-watershed during the peak year of CBM water production is about 12 cfs (8,689 acre-feet/year). Impacts to surface water quality in the Little Powder River sub-watershed would be less than are described under Alternative 1, and similar to those described for Alternative 2A. Additional water would be available to support beneficial use because of the proportion of water that would undergo active treatment.

Alternative 3

Under Alternative 3, the peak year of water production in the Little Powder River sub-watershed would occur in 2005, when 2,093 wells would be producing at an average rate of 6.2 gpm per well. Managed water losses would be the same as under Alternative 1. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Little Powder River sub-watershed during the peak year of CBM water production is about 15 cfs (10,861 acre-feet/year). Impacts to surface water quality in the Little Powder River sub-watershed would be similar to those described under Alternative 1.

Cumulative Surface Water Impact Analysis

Results of the cumulative impact analysis in the Powder River Basin under Wyoming's Alternative 2A and Montana's Alternative E are presented in Table 4–13. The analysis at the Tongue River station near Ashland, Montana, incorporates all existing and future forecast CBM development in the Tongue River watershed from Wyoming and Montana. The analysis at the Powder River station at Locate, Montana, incorporates the existing and future forecast CBM development in the Little Powder and Powder River drainages in Wyoming and the portions that lie within Montana. Potential impacts to water quality are discussed briefly below and in detail in the SWQATR that has been prepared in support of this analysis.

Table 4–13 Cumulative Surface Water Impact Analysis

Station	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC	SAR	EC	Flow	SAR	EC	Flow	SAR	EC
Tongue River at Brandenberg Bridge near Ashland, MT	0.5	500	10	2,500	207	1.36	1,016	214	2.50	1,058
Powder River at Locate, MT	2.0	1,000	10	3,200	143	4.61	2,287	236	11.4	2,320

The water quality in the Tongue River at Ashland, Montana currently, exceeds the MRPL for EC and SAR. Thus, any additional discharge that would reach the main stem would likely cause further degradation in terms of suitability for irrigation if the states and the EPA conclude that the MRPL is protective of irrigation uses. During low-flow conditions, surface water flow in the Tongue River would increase moderately. The resultant water quality in streams would increase slightly in EC and SAR from existing conditions. Both constituents would be at concentrations less than the LRPL. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates that there is not likely to be a reduction in infiltration during mean monthly or 7Q10 flow conditions.

The water quality in the Powder River at Locate, Montana, currently exceeds the MRPL for EC and SAR. Thus, any additional discharge that would reach the main stem would likely cause further degradation in terms of suitability if the states and EPA conclude that the MRPL is protective of irrigation. During low-flow conditions, flow of surface water in the Powder River would increase approximately twofold. The resultant water quality in the stream would increase slightly in EC and, more significantly, in SAR from existing conditions. With the exception of the SAR during minimum mean monthly flow, both constituents would be at concentrations less than the LRPL. A comparison of the resultant quality of mixed water with the Ayers-Westcot diagram indicates that there is not likely to be a reduction in infiltration except during 7Q10 flow conditions.

Modeling indicates that the suitability of the Tongue River for irrigation may be compromised by the surface discharge of CBM produced water during maximum CBM development in both states. However, existing interstate agreements have been developed to minimize impacts until protective standards are put in place and the assimilative capacity is equitably divided among the states and tribes. Surface discharge to the Tongue River from CBM development in both states currently is controlled by the two state DEQs. These agencies have agreed to an interim "no new discharge" policy that would not authorize untreated surface discharge of CBM waters to the Tongue River unless the water quality was at or near the existing level in the Tongue River.

Cumulative effects to the suitability for irrigation of the Powder River would be minimized through the interim MOC that the two DEQs have signed. This MOC was developed to ensure that designated uses downstream in Montana would be protected while CBM development in both states continued. As the two states develop a better understanding of the effects of CBM discharges through the enhanced monitoring required by the MOC, they can adjust the permitting approaches to allow more or less discharges to the Powder River drainage. Thus, through the implementation of instream monitoring and adaptive management, water quality standards and interstate agreements can be met.

Of course site-specific conditions and the actual surface water standards adopted by the MBER will be the most important factors in determining the actual water management practices within the Montana portion of the PRB. The MDEQ cannot allow discharges of CBM water to impact surface water conditions in excess of prevailing regulations and standards. CBM producers in the Wyoming portion of this watershed will be held to the same standards if the Montana standards are approved by the EPA and given CWA standing.

Effects from each Alternative Common to All Sub-Watersheds

Alternative 1

Surface Drainages

Potential effects from discharges of CBM produced water to surface drainages within the Project Area include alteration in flow, erosion, degradation of the stream channel, and increased sedimentation. Potential effects would be most pronounced during periods of historical low flow. Surface drainages may be affected by the discharge of CBM produced water where channels are not stable, armored, or large enough to accommodate the anticipated flows. Localized flooding may occur with increased frequency and magnitude where the capacity of the channel or basin is insufficient to handle the increased flows. In contrast to naturally occurring flows, which fluctuate significantly with changing seasons, flows generated by discharges of CBM produced water occur year-round with small fluctuations. Site-specific Water Management Plans (Appendix I) submitted at the APD and POD level of analysis would be an integral part of mitigation planning to control and monitor the potential effects from increased flows in surface drainages.

Conveyance losses caused by evapotranspiration and infiltration would minimize the volume of discharged CBM produced water that would reach the main stems of surface drainages. However, draws that previously were ephemeral could become perennial downstream from clustered outfalls that discharge large volumes of CBM produced water. Modeled conditions assumed a single conveyance loss, whereas actual conveyance loss would vary. Higher conveyance losses would correspond to unsaturated stream channel conditions. Locating surface discharge outfalls higher up in ephemeral or intermittent drainages would encourage conveyance loss, as these drainages would essentially be under unsaturated conditions. Conveyance losses would be minimal when CBM produced water is discharged into perennial waterways. Conveyance losses would likely be significantly reduced during prolonged cold winters, enhancing runoff and areas of standing water during the spring melt.

Wyoming's 2002 Clean Water Act 303(d) list identifies water bodies within the Project Area that do not support all of the designated uses (WDEQ 2002b). Pollutants of concern causing existing impairments to water quality in the Upper Tongue River, Upper Powder River, and Upper Belle Fourche River sub-watersheds include temperature, selenium, chloride, and fecal coliform. CBM discharges should not aggravate the impaired waterbodies for these pollutants of concern on the listed waterbodies. If these pollutants do become a concern from CBM discharge, they would be controlled through the NPDES permit. Surface drainages would also likely exhibit iron staining below designated outfalls, where CBM produced water that is typically high in iron would be discharged. Iron staining would be less evident in the Upper Tongue River, Clear Creek, and Middle Powder sub-watersheds where NPDES permit requirements for passive treatment of iron in CBM discharges would apply.

As surface discharge of CBM produced water continues, the creeks and draws in the upper basin would become saturated and runoff rates are likely to increase, thus producing more water during storms. High seasonal flows during the spring would be expected to rise with the addition of CBM produced water. Channels may be more likely to overbank during snowmelt, flooding nearby fields. Localized erosion and formation of gullies, water-damaged structures, inundated vegetation, siltation, or breaching of irrigation structures may result from large, late, or prolonged floods. However, numerous impoundments constructed to store CBM produced water for beneficial use also would serve as effective structures for flood control, provided facilities were sited and constructed in accordance with WDEQ, WSEO, and WOGCC requirements. Increased surface flows also could fill channels and culverts with ice during the winter, causing localized flooding. Closed basins or playas (old lakebeds) may become inundated if CBM produced water is discharged into them.

Although drainages would not be expected to flow under completely natural conditions during the life of the project, the enhanced CBM flows are not expected to alter surface drainage patterns, except as noted. Streams enhanced by large volumes of CBM produced water may begin to establish meander patterns on longer wavelengths in response to increased flows. Stream drainages would readjust to their existing natural flows at the end of the project's life.

Downcutting (stream erosion) and sediment deposition (aggradation) are natural processes that occur as stream drainages age through time. Downcutting occurs within the upper reaches of a drainage system as the stream channel becomes incised through erosion, until the slope of the stream and its velocity are reduced and further erosion is limited. Sediment is deposited within the lower, slower reaches of a stream.

Surface drainages could be degraded from erosion caused by increased surface flows, unless rates of CBM discharge and outfall locations are carefully controlled. Increased flows could cause downcutting in fluvial environments, resulting in increased channel capacity over time within the upper and middle reaches of surface drainages. Ravines or gullies are likely to develop unless outfalls are carefully located and designed where downcutting occurs in highly erodible soils. The design should avoid surface discharge above existing headcut areas.

Sediment transported downstream from outfalls likely would be deposited in fluvial settings as stream gradients decrease within lower reaches of drainages. Wherever sediment is deposited, the channel capacity likely would decrease over time. This decrease may increase the likelihood that localized flooding may occur. A new balance between channel capacity and floodplain morphology would be established as the proposed project is implemented, and would be reestablished at the end of the project's life. Where the quality of produced water and landowner preferences allow construction of stock reservoirs to store some surface flows for beneficial use, these structures likely also would serve as effective flood control measures during intense storms. These impoundments would be located in-channel or near-channel and would be designed and sited in accordance with WSEO, WDEQ, and WOGCC requirements.

Overbank deposits (produced during floods) can yield nutrient-rich and arable soils, which may enhance the agricultural uses of the affected lands. Alternatively, overbank deposits may add saline or fine-grained sediments to a floodplain, decreasing productivity and lowering infiltration rates through the addition of materials with elevated SAR values. The latter could occur in sub-watersheds that are affected by saline soils, soils developed from shales, or CBM produced water that contains elevated SAR values.

In sub-watersheds where LAD is used as a method of produced water management, surface salts left behind could reach surface drainages during prolonged storms. Winter operation of LAD systems could build up ice on the surfaces of soil during sub-freezing temperatures. Site-specific Water Management Plans submitted at the APD and POD level of analysis would be an integral part of the mitigation planning to control and monitor the potential effects from LAD.

Springs

New springs may develop in areas where infiltration of CBM produced water is recharging alluvial aquifers or Wasatch sands. Spring flow may be inhibited locally if compaction occurs during construction or production. Natural discharge from springs can be affected by a reduction in hydraulic head within the source aquifer. It is unlikely, however, that new springs would develop near properly engineered and constructed containment impoundments, provided facilities are sited and constructed in accordance with WDEQ, WSEO, and WOGCC requirements.

Water Bodies

Large reservoirs located within or downstream of the [illegible] Area (Lake De Smet in the Clear Creek sub-watershed, Keyhole Reservoir in the Upper Belle Fourche River sub-watershed, and Angostura Reservoir in the Upper Cheyenne River sub-watershed) potentially would receive surface flows that contain CBM produced water. Loads of suspended sediment to these reservoirs are not likely to increase as a result of surface discharge of CBM produced waters. Conversely, large flushing flows from infrequent storm events would continue to be the major carriers of sediment load. As surface streams transport suspended sediment downstream, their ability to acquire and transport additional sediment would decrease. However, these large reservoirs would serve as sediment traps so that discharges or releases from these reservoirs would not be compromised by suspended sediment loads. More than half of the smaller permitted surface water impoundments in the Project Area could also receive surface flows that contain CBM produced water.

In-channel impoundments used to manage produced water would be designed as flow-through structures and would be properly permitted by WSEO. No existing surface water right would be expected to be affected by this method of water handling. Off-channel impoundments used to manage produced water would be properly permitted by WSEO. Shallow groundwater systems and surface waters would not be expected to be affected by this method of water handling, provided facilities are designed and sited in accordance with WDEQ, WSEO, and WOGCC requirements.

CBM produced waters discharged to off-channel containment impoundments would require an NPDES permit issued by WDEQ, which would establish effluent limitations that would be protective of use by livestock and wildlife. Concentrations of salts and trace metals, particularly selenium, may become elevated in the water contained in these impoundments as evaporation occurs. Water quality could reach levels of concern for various constituents when inflow to the impoundments ceases and NPDES permit monitoring requirements no longer apply. Sediments left behind after the water evaporates may require special handling during reclamation. The quality and quantity of CBM produced water that may reach surface impoundments should be carefully monitored and addressed in management planning for each area affected by CBM development. Potential effects on surface water impoundments should be analyzed on a site-specific basis, as needed, during review of water management plans submitted at the APD or POD level of analysis. Impacts should be mitigated through application of special conditions of approval.

Infiltration rates in impoundments used to manage produced water may decline over time. CBM produced waters high in sodium may disperse the clay soil particles and decrease the permeability of soil for impoundments constructed in clayey soils, thus decreasing the rate of infiltration. Impoundments constructed in sandy soils would be less affected by increased concentrations of sodium over time, and infiltration rates would likely be maintained over the life of the impoundment. Percolation rates and characteristics of the soil beneath infiltration impoundments should be carefully monitored and addressed in water management planning for each area that would be affected by CBM development. Potential effects on infiltration impoundments should be analyzed on a site-specific basis, as needed, during review of water management plans submitted at the APD or POD level of analysis. Effects should be mitigated through application of special conditions of approval.

Surface Water Use

Produced water from CBM wells is most likely to be beneficially used for irrigation, livestock watering, wildlife, wildlife habitats, and fisheries. Produced water would be available for limited use for dust suppression on access roads to wells under WOGCC guidelines. Water discharged to surface drainages would be

94

available for appropriation and diversion under WSEO authorizations. Agricultural and livestock operations would thus obtain additional surface water to manage and use. Discharge and storage of CBM produced water on upland areas in the Project Area would disperse livestock and wildlife and offer the benefit of better use of forage and reduced overgrazing and erosion.

Alternative 2A

Under Alternative 2A, effects to surface drainages, springs, surface water bodies, and surface water use would be similar to those described for Alternative 1, with the exceptions noted below.

Surface drainages would be less affected by alteration in flow, erosion, and sedimentation than under Alternative 1 because of the changes in management of produced water and decreased surface discharge of CBM produced water. Surface drainages would be less likely to exhibit iron staining below designated outfalls as NPDES permit requirements for passive treatment of iron in CBM discharges would apply to those sub-watersheds where discharge would occur. Effects from surface water impoundments designed as infiltration basins may be greater than under Alternative 1 because of the larger proportion of CBM produced water managed in these impoundments. The siting guidance established by WDEQ, WSEO, and WOGCC for these impoundments would minimize the effects.

Effects from LAD would increase from Alternative 1 because of the higher proportion of LAD used for handling CBM produced water. Potential effects from LAD would occur in those sub-watersheds where the systems were not implemented under Alternative 1, specifically in the Upper Tongue River, Upper Powder River, Salt Creek, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds. The amount of water available to support beneficial use for livestock and wildlife would increase from Alternative 1 because of the smaller percentage of direct surface discharge. The amount also would rise as a result of the increase in water handling through infiltration impoundments.

Alternative 2B

Under Alternative 2B, effects to surface drainages, springs, surface water bodies, and surface water use would be similar to those described for Alternative 1, with the exceptions below.

Surface drainages would be less affected by alteration in flow, erosion, and sedimentation than under Alternative 1 because of the changes in management of produced water and decreased surface discharge of CBM produced water. Surface drainages would be less likely to exhibit iron staining below designated outfalls as NPDES permit requirements for passive treatment of iron in CBM discharges would apply to those sub-watersheds. With the exception of the Upper Belle Fourche, additional water would be available in all sub-watersheds where CBM development is proposed to support beneficial uses through implementation of some level of active treatment. Treated water would be stored in infiltration ponds and would be available to blend with additional CBM discharges before surface discharge. CBM produced water that has been treated before it is discharged to surface impoundments would have less effect on the soils beneath the impoundment, depending on the level of treatment. Thus, rates of infiltration would be less likely to decline over time if the impoundments are situated on clayey soils.

Effects from complete containment impoundments would be less than under Alternative 1. The number of large containment impoundments would decrease, and the number of smaller infiltration ponds constructed to facilitate stock watering and other beneficial uses would increase, because of the higher percentage of better-quality water from active treatment. Sediments left behind in surface impoundments would be less likely to require special reclamation, provided some of the water discharged to the impoundments has undergone treatment. The treatment of CBM produced waters could result in the generation of residues that would contain concentrated salts extracted from the CBM water. These residues would need to be analyzed on a case-by-case basis during water management planning and proposed treatment implementation to determine their characteristics and disposal requirements.

Alternative 3

Under Alternative 3, effects to surface drainages, springs, surface water bodies, and surface water use would be similar to those described for Alternative 1; however, the magnitude of effects would be less because of the decreased volume of CBM produced water that would be discharged to surface drainages and surface water impoundments throughout the Project Area.

Cumulative Effects Common to All Sub-Watersheds

Alternative 1

Surface Drainages

Both mining and CBM development result in water collection and discharge to surface drainages. Groundwater encountered during mining is stored in sedimentation ponds. Much of this water is used for dust suppression during mining and is not discharged to surface drainages, except during certain storms. Discharges from the sedimentation ponds could contain higher concentrations of dissolved solids and be of lower quality because of sediment mixing during precipitation and concentration through evaporation. In contrast, CBM water produced from wells is essentially free of sediment, although discharge to surface drainages can increase sediment loading caused by increased stream erosion.

Active coal mines are located within three sub-watersheds in the Project Area: the Upper Belle Fourche River, the Little Powder River, and the Upper Cheyenne River sub-watersheds. TDS values of mine discharges from sedimentation ponds to these drainages would not likely cause any discernible effects to existing water quality compared with effects from CBM discharges. Mine discharges are typically intermittent and the water quality is likely similar in composition to the natural water quality in streams. Discharges from surface coal mines are also subject to the requirements of WDEQ's NPDES program.

Culverts that carry water from upstream reaches of sub-watersheds that are undergoing CBM development may have to be re-sized. Diversion channels for natural flows also may have to be re-sized to handle additional flows. Mining operations that partially treat water in sedimentation reservoirs may have to treat additional water. In these situations, the water quality at the mine NPDES outfalls may be affected by CBM discharge that commingles with water from the surface mines. Potential effects on mine operations should be analyzed on a site-specific basis, as needed, during review of CBM PODs or water management plans. Impacts should be mitigated through application of special conditions of approval.

By the end of the project's life, some surface drainages within the Project Area may be slightly deeper than they are today as a result of erosion. Careful siting and design of surface discharge outfalls would prevent or mitigate this impact. Downvalley, a careful observer may notice a few more bar or beach deposits within perennial streams or rivers than today.

South Dakota's 2002 303(d) list identifies water bodies downstream of the Project Area that do not support all of the designated uses (SDDNR 2002). Existing impairments to water quality caused by sedimentation and salinity in the Cheyenne and Belle Fourche Rivers could be aggravated by discharges of CBM produced water to surface drainages in those sub-watersheds. Increased sedimentation may occur in the Upper Cheyenne River sub-watershed through expansion in the PRB of the DM&E Railroad Corporation. Sediment loading to downstream segments in South Dakota currently listed as impaired by sedimentation could increase. BMPs implemented as required by NPDES permits during railroad construction would minimize additional sediment loading to the drainage, however. Monitoring existing conditions at the state line between Wyoming and South Dakota would allow WDEQ to continually revise its permitting strategy for CBM discharges in the affected drainage. Monitoring also would facilitate development of TMDL wasteload allocations that are protective of existing and future uses in both states.

Segments of the Tongue, Powder, and Little Powder Rivers in Montana downstream of the Wyoming border appear in Montana's 2000 303(d) list for water quality impairments caused by siltation and alteration in flow (MDEQ 2002). Discharges of CBM produced water to these drainages could aggravate the existing impairments. TMDLs are scheduled for development in 2002 and would be used to protect the water quality in those streams and guide future CBM development in both states.

Springs

Spring flows may have changed from present conditions. Potential effects on existing springs should be analyzed on a site-specific basis, as needed, during review of water management plans submitted at the APD or POD level of analysis. Impacts should be mitigated through application of special conditions of approval.

Water Bodies

Reservoirs downstream of the Project Area likely would receive more water and could take in additional sediment as a consequence of CBM development. The large capacity of these reservoirs would likely minimize any increases in concentrations of suspended sediment that may occur as a result of CBM development in upstream drainages. Additional water would better support adjudicated water uses downstream.

Water Use

Agricultural and livestock operations would obtain additional surface water to manage and use during the life of the project. Stock watering and irrigation likely would increase within the area of cumulative effects.

Alternative 2A

The cumulative effects on surface drainages, springs, surface water bodies, and surface water use would be similar to those described under Alternative 1, with the exceptions noted below.

Sediment loading to downstream reservoirs would be less than under Alternative 1 because of the decreased percentage of surface discharge of CBM produced water. Infiltration impoundments constructed in -channel would further minimize sediment transport downstream to the larger reservoirs. Sedimentation may increase in surface waters adjacent to infiltration impoundments, as the impoundments are reclaimed at the end of the project's life. BMPs for erosion and sediment controls would mitigate increases in sedimentation in surface drainages during reclamation of the impoundments.

Alternative 2B

The cumulative effects on surface drainages, springs, surface water bodies, and surface water use would be similar to those described under Alternative 1, with the exceptions noted below.

The number of surface impoundments that would remain at the end of the project's life would be greater than under Alternative 1 because additional impoundments would have been constructed to contain water that had been actively treated for beneficial use. Many of these impoundments may not be reclaimed, depending on the desires of the surface owners, so that increases in sedimentation in surface drainages during reclamation would be minimized. The water available for treatment and beneficial use would decline toward the end of the project life, as the rate of discharge from wells decreases over time. Ranchers and surface owners that depended on the additional water supply to support beneficial use may need to consider alternative water supplies.

Alternative 3

The cumulative effects on surface drainages, springs, surface water bodies, and surface water use would be similar to those described under Alternative 1. However, the magnitude of effects would be reduced because of the decreased volume of CBM water that would be discharged to surface drainages and surface water impoundments throughout the area of cumulative effects.

Physiography, Geology, Paleontology and Mineral Resources

Paleontology

Paleontological resources are fragile and, once disturbed, lose much of their preserved information. Avoidance of significant sites is the preferred mitigation measure for adverse effects on paleontological resources.

Within the Powder River Basin Project Area, the construction of oil and gas-related facilities, including access roads, could adversely affect scientifically significant fossils. The potential for impact to significant fossils is greatest in areas where Class 3, 4, or 5 formations are present. Both surface and subsurface fossils could be damaged or destroyed during ground-disturbing activities. The greatest potential impact to surface and subsurface fossils comes from excavations of surface sediments and shallow bedrock. These types of excavations are commonly associated with well pad, pipeline, access road, and building construction. Drilling may affect fossils, but because this impact is not visible, verifiable, or preventable, the impact to significant fossils posed by drilling is considered low.

Across the Project Area, occurrences of surface fossils could be rejuvenated at previously collected fossil localities within as little time as 1 year. In addition, surface fossil concentrations could develop where no fossils were present before wherever fossiliferous rocks are exposed by erosion.

During initial discussions with a CBM operator before an APD is submitted, the BLM, or FS where appropriate, will indicate whether proposed ground-disturbing activities may affect significant paleontological resources. Activities that may affect significant paleontological resources would require an assessment or survey to evaluate whether significant resources occur in the area of the proposed action, and whether the action would affect these resources.

In most cases, given the small size bias of Wasatch Formation fossils in the PRB, individual construction sites should be able to be cleared of all significant fossils prior to construction. The discovery of significant paleontological resources during a pre-construction survey would require mitigation of possible impacts to these resources before ground-disturbing activities begin. It is unlikely that any fossils discovered during pre-construction surveys or monitoring phases would delay construction.

In addition to adverse impacts during construction, significant fossils may become exposed during subsequent erosion of freshly excavated rocks at construction sites. In Class 3 or 5 formations, post-construction paleontologic inspections may be recommended, depending on the results of the pre-construction survey.

APD conditions of approval include mitigation measures where necessary, and would require protection and prompt reporting of paleontological resources discovered during post-construction activities. In that case, operations would be suspended until an evaluation of the discovery and mitigation are completed.

99

All facilities located on federal surface ownership lands would be considered federal undertakings, subject to federal guidelines and regulations protecting paleontological resources. Where oil or gas development excludes federal leases or surface ownership lands, no federal permits are required to develop these lands, and protection measures for paleontological resources might not be mandated by the landowners or monitored as closely.

Alternative 1

Development of oil or gas resources on federal leases would be considered a federal undertaking, subject to federal guidelines and regulations protecting paleontological resources. However, only a portion of the facilities associated with fee and state wells developed under Alternative 1 are likely to be located on federal surface ownership lands and would be considered federal undertakings.

Surface disturbance associated with construction would increase the potential for paleontological resources to be affected. Only portions of the Project Area have been evaluated for the occurrence of paleontological resources. As a result, no accurate estimate can be made of the number of paleontological sites that may be affected based on the 156 localities that have been recorded.

Surface disturbance typically associated with CBM development in the Project Area, that is, use of two-track roads and natural terrain without vegetation removal and drill pads or pipelines requiring minimal cut-and-fill excavations, would limit the effect of ground-disturbing activities on subsurface paleontological resources. Although paleontological resources contained in near-surface horizons of soil and surficial deposits likely already have been disturbed by natural processes or human activity, there could be additional disturbance to paleontological resources. Access across natural terrain without vegetation removal and limited use of shallow excavations likely would have minimal additional effect on these resources. Surface use and shallow excavations likely would have little or no effect on undisturbed paleontological resources occurring below the surface.

Where federal undertakings associated with oil or gas development are involved, potential effects on paleontological resources would be analyzed on a site-specific basis, as needed, during review of APDs, Sundry Notices, ROWs, or Special Use Permits, and effects eliminated or minimized through the application of special conditions of approval for operations. Where direct effects cannot be avoided, an approved data recovery plan would be developed to mitigate the adverse effects.

The development of fee and state wells would not be considered federal undertakings, and would not be subject to federal guidelines and regulations protecting paleontological resources. Unprotected paleontological resources potentially could be disturbed, damaged, destroyed, or removed from the site, losing much or all of their preserved scientific information.

Alternative 2

Effects on paleontological resources likely would be similar to Alternative 1.

Alternative 3

Under Alternative 3, additional development of federal leases would not be authorized once existing authorizations under the Wyodak CBM Project EIS and the Wyodak Drainage CBM EA have been exhausted. Oil or gas development of fee and state leases under Alternative 3 would involve far fewer federal undertakings subject to federal guidelines and regulations protecting paleontological resources than Alternatives 1 or 2. Consequently, the number of paleontological resources likely to be affected would be smaller.

Only a portion of the facilities associated with fee and state wells developed under Alternative 3 are likely to be located on federal surface ownership lands and would be considered federal undertakings. Where oil or gas development involves federal surface ownership lands, effects on paleontological resources likely would be similar to Alternatives 1 and 2.

The development of fee and state wells under Alternative 3 would not be considered a federal undertaking, and would not be subject to federal guidelines and regulations protecting paleontological resources. Unprotected paleontological resources potentially could be disturbed, damaged, destroyed, or removed, losing much or all of their preserved scientific information.

Mineral and Energy Resources

Alternative 1

Methane would be produced from federal, state, and fee CBM wells drilled into underlying coal seams in the Project Area. Based on an average production rate of 160,000 cubic feet of CBM per well per day following initial dewatering, and an average of 400 million cubic feet of CBM available per well (De Bruin et al. 2001), an estimated 16 trillion cubic feet of methane would be produced over the life of the CBM wells included in Alternative 1. Initial production rates during the first few years of production are expected to be higher and then steadily decline during the rest of the well's economic life.

CBM development in the PRB has been concentrated on fee and state leases for several years, causing drainage of CBM resources from federal leases. Drainage of CBM resources from federal lease areas would continue to occur under Alternative 1, as development of federal leases likely would continue to lag behind the development of fee and state leases. CBM development on federal leases in some extensively drained areas may no longer be economically feasible. In addition, development of CBM in Montana may result in drainage to Wyoming lands by wells just across the state boundary. The BLM is continuing to analyze the ongoing and anticipated levels of drainage within the Project Area and Wyoming BLM's Reservoir Management Group would continue to work with BLM in Montana to address drainage of CBM across the state boundary.

Oil and gas would be produced from non-CBM wells drilled into underlying geologic formations or structures in the Project Area. This analysis used the following assumptions made by the BLM (BLM 2001f) to estimate the anticipated production of oil and gas from non-CBM wells. Based on a mix of oil and gas dis-

101

coveries (80 percent of new fields discovered would contain oil and 20 percent of new fields discovered would contain gas), the expected success ratio for the 3,200 new exploratory wells drilled (15 percent), the anticipated number of productive wells (480), the average life of a productive well (15 years), average production of 137,800 barrels of oil equivalent (BOE) over the life of each productive well, and the anticipated average size of new fields (five wells), an estimated 66,144,000 BOE would be produced from the non-CBM wells included in Alternative 1.

Past conflicts in the Project Area between CBM development and expanding surface coal mining operations indicate potential new conflicts may arise. BLM stipulations mandating specific timing of activities or precluding CBM development from some mine areas would be applied unless potential conflicts are resolved through sponsored cooperation among affected interests that would result in mutual agreements for affected areas.

Development of CBM occurring upstream of nearby surface coal mines could affect coal mining. CBM produced water discharged upstream of mines could increase surface flows near coal operations or decrease the rate of groundwater withdrawals that currently accompany ongoing coal mining operations. Changed conditions could affect the design or permitting of coal mining operations and the mining schedule for specific areas.

Sediment control structures located in the permit areas for coal mines likely would be affected by increased surface flows anticipated under Alternative 1. These structures have been designed to accommodate historical flow rates that do not include contributions from CBM generated flows. Some design aspects of mining operations may need to be changed. Any required revisions to approved mine plans would affect the operators and agencies involved in reviewing proposed changes. Timeframes needed to change design aspects of mining operations may affect the timeframes for initiation of CBM discharges. CBM generated flows are not likely to be lower quality (that is, TDS is elevated over existing flows). The effects on the availability of groundwater for mining operations and the effects of increased surface flows on mine facilities could be mitigated on a site-specific basis through cooperative agreements among CBM developers and mine operators, as potential effects are identified.

Water production rates, conveyance losses, water chemistry, and water handling methods and their effects have been estimated for sub-watersheds that contain surface coal mines. This additional discussion occurs in the section of this chapter on Surface Water. The relative locations of sub-watersheds, surface coal mines, existing and projected CBM wells, and existing water wells are shown on Figure 2–1 to assist in this discussion.

Although conflicts between CBM drilling and existing or potential surface coal mining may occur, the economic value of the coal resource would not be affected. Development of CBM wells would be precluded in areas of active or impending coal mining. In areas where coal mining occurred before CBM development began, valuable CBM resources and royalties would not be recovered from the mined area.

102

Locating CBM wells in areas where future mining may take place would preclude mining during the life of CBM wells located in the area proposed. Coal in these areas could be mined after CBM extraction is completed or terminated, or after an agreement is negotiated between the CBM developers and the coal mine operators. The effects on mining schedules could be mitigated on a site-specific basis through cooperative agreements among CBM developers and mine operators, as potential effects are identified.

Subsurface uranium deposits located in the southwestern portion of the Project Area are associated with Wasatch Formation sandstones. Withdrawal of CBM and water from the stratigraphically lower Fort Union Formation would not be likely to include uranium-bearing waters unless poor well completion techniques were to result in incomplete isolation of the Wasatch and Fort Union aquifers. WOGCC requirements for well completion would eliminate the possibility that commingled groundwater from the Wasatch and Fort Union Formations would be withdrawn during CBM development.

Development of CBM is not likely to affect the recovery of uranium resources from in situ (in place) subsurface leaching of sandstones. However, if infiltration of sulfate-rich water into mining areas were to occur, uranium might precipitate prematurely, decreasing recovery rates. Since water produced from Fort Union Formation coal beds is exclusively sodium bicarbonate-type water (Rice et al. 2002), infiltration of sulfate-rich water would not be likely to occur during CBM development under Alternative 1.

Interactions between development of CBM and subsurface uranium deposits would be analyzed on a site-specific basis at the APD or POD level of analysis, as APDs and PODs for federal CBM wells are reviewed by BLM, and the FS as appropriate. Site-specific mitigating measures relating to a specific CBM well or group of CBM wells will be developed based on that analysis.

Development of CBM under Alternative 1 would not be likely to affect recovery of other mineral resources n the Project Area. Oil and gas have been produced from geologic formations occurring several thousand feet below the coal zone. Salable minerals, primarily clinker, sand, and gravel, are produced from surface deposits. Bentonite, high-calcium limestone, and gypsum occurring in rocks exposed along the uplifted margins of the study, are stratigraphically below the geologic formations that may be affected by CBM development in the PRB. No other locatable mineral deposits are known to exist in the Project Area. Development of existing mineral rights in the Project Area would be based on existing claims, lease terms, and agreements; future conflicts would be addressed on a case-by-case basis.

Alternative 2

Effects on mineral and energy resources would be similar to under Alternative 1.

Alternative 3

Effects on mineral and energy resources would be similar to Alternative 1; however, the exclusion of federal wells and the overall reduced number of CBM wells under Alternative 3 would result in some variations from the effects de-

BEST COPY AVAILABLE

103

scribed under Alternative 1. The magnitude of the effects on mineral and energy resources under Alternative 3 likely would be reduced. Drainage of CBM resources likely would be greater under Alternative 3, as more new drainage situations would be created by the exclusion of federal wells from projected activities.

Geologic Hazards

Potential effects, such as creating new geologic hazards, are not likely to occur. Some existing hazards, such as landslides, flooding, or gas migration and seepage could worsen unless adequate monitoring and mitigation are required. As part of the APD approval process for federal lease development, BLM, and FS when involved, require consideration of geologic hazards contained in all areas where ground-disturbing activity is proposed. APD conditions of approval would require mitigation of effects.

All facilities located on federal surface ownership lands would be considered federal undertakings, subject to federal guidelines and regulations for environmental protection. Where oil or gas development excludes federal leases or surface ownership lands, no federal permits are required to develop these lands, and protection measures for geologic hazards might not be mandated by the landowners or monitored as closely.

Alternative 1

Earthquakes

In portions of the Project Area where underground injection would be used as one of the methods of handling the water produced by CBM wells, no excessive buildup of rock pressure or fracturing of rocks that could cause an earthquake to occur would be anticipated during injection activities. Therefore, no earthquakes associated with underground injection would be expected to occur. Underground injection to dispose of produced water would be used in accordance with federal and state regulatory requirements. Injection wells would be authorized only where the injection zone is sufficiently porous and permeable that fluids could enter the rock formation without causing an excessive buildup of pressure or fracturing of rocks.

Flooding

Anticipated CBM flows could increase the frequency or magnitude of flooding anticipated in the Project Area. Minimization of flood hazards within the Project Area would depend on the use of mitigating measures to ensure adequate control of anticipated surface flows and design of impoundments. Comprehensive water management planning, including development and implementation of BMPs for discharge outfalls and water development structures, would mitigate the effects of anticipated CBM flows. However, lower than anticipated flood damage during an intense storm near Gillette in May 2000 demonstrated that management of existing CBM flows, including construction of many small reservoirs, reduced the severity of flooding in the Project Area in one case.

Landslides

Surface disturbance could worsen existing and could create new landslide hazards in the Project Area. Mass movements likely would increase within the Project Area, damaging resources and property, unless disturbance to existing landslides and areas susceptible to movement, such as steep slopes or unstable soils, is avoided or mitigated during oil or gas development. Landslides could be triggered during oil or gas development; however, design of operations to incorporate BMPs and mitigation measures that minimize landslide risks would reduce the potential for landslides to increase within the Project Area.

Surface disturbance could cause or worsen the continuing migration of windblown sand deposits along the southeastern and eastern margins of the PRB, unless disturbed areas are stabilized promptly with vegetative cover. Continuing migration of windblown deposits would contribute to soil loss, if existing soils were blown away with sands. Increased sedimentation in surface drainages also would result from the migration of sand deposits.

Aquifer Compression and Ground Subsidence

Development of CBM is not likely to cause noticeable ground subsidence or aquifer compression in the Project Area. Where unconsolidated alluvial aquifers have collapsed in other geographic areas through dewatering, significant ground subsidence has occurred. However, the Fort Union Formation is a consolidated rock unit and is not as susceptible to aquifer compression or collapse as an unconsolidated unit. In addition, based on its estimated storage coefficient and recognized depth from the surface to the coal zone aquifer where decline in the hydraulic head could occur, the Fort Union Formation could not be dewatered enough to cause noticeable ground subsidence.

Case et al. (2000) describe the formula used to calculate the amount of aquifer compression that occurs when water is withdrawn from an aquifer. The change in aquifer thickness is equal to the storage coefficient times the change in head. The storage coefficient is measured through a pump test and the change in head is observed (or monitored) over time as declines in water level.

The storage coefficient used by Case et al. (2000) for PRB producing coals and underlying sands (1.0×10^{-4}), represents the best estimate available for the storage coefficient applicable to the Fort Union Formation. Since the Big George coal zone occurs between 1,000 and 2,000 feet below the surface in the central portion of the PRB, a theoretical drawdown to the top of the Big George coal zone could be up to 2,000 feet in the central portion of the PRB. Applying the formula described above allows consideration of the largest aquifer compression theoretically possible in the central portion of the PRB. A decline in hydraulic head to the top of the Big George coal zone is not, however, projected in this analysis of the environmental effects under Alternative 1.

Aquifer compression in the central portion of the PRB caused by withdrawal of fluid (CBM produced water) theoretically could be 2.4 inches, if the hydraulic head in the Fort Union Formation declined to the top of the Big George coal zone, although a decline of this magnitude is not projected under Alternative 1. The compressibility of an aquifer decreases with increasing depth (Edgar and Case 2000). Therefore, CBM development of deeper coals, such as the Big

George zone, likely would result in less actual aquifer compression than is calculated above. In addition, the entire aquifer compression likely would not be transmitted to the surface, so that no ground subsidence would be noticeable even under maximum theoretical drawdown. The effects of aquifer compression under Alternative 1 would be even less, and would not be noticeable.

Gas Migration, Seepage, and Venting

Limited information is available for use in characterizing methane mobility and anticipated movements in the PRB over time. As a result, methane seepage in the PRB has not been quantified in a model projection. Gas migration and seepage are naturally occurring processes where coal beds are extremely close to the surface and can be enhanced during coal mining and CBM development. Gas migration and seepage would be most likely to occur near production areas along the coal outcrop. Gas migration and seepage also could occur within or near CBM production areas, where substantial dewatering has occurred or is occurring.

Dewatering of the coal during development of CBM that lies beneath Gillette lowers the water table, which in turn, may allow gas to seep. Production of gas from CBM wells may help prevent or limit seepage, however (Flores et al. 2001). Production of CBM removes methane from the coal zone aquifer, making less methane available to migrate through underground faults, fractures, or sandstone layers or escape at the surface in seeps.

Completion procedures for CBM wells are designed to direct methane toward the well bore and would not induce methane to migrate away from the well bore, toward existing water wells. Production of CBM is strictly controlled within casing that is cemented and is not likely to cause any release of methane into the groundwater. WOGCC and BLM requirements for well drilling and control procedures ensure that each formation remains as isolated as under natural conditions and that the integrity of the well bore remains intact, eliminating the possibility for methane migration in CBM wells.

However, many existing non-CBM well bores likely do not effectively isolate the formations penetrated and may serve as conduits for the vertical migration of methane. Many older conventional oil and gas wells likely are inadequately cased or plugged, allowing methane, if present, to migrate. Migration of methane could be enhanced where these potential conduits are located near coal mining or CBM production areas.

Methane could emerge from water wells near coal mining or CBM production areas, affecting stock and residential wells. Water wells frequently are screened over multiple aquifer zones, which would facilitate methane migration through the well bore. The migration of methane could be enhanced where water wells are located near coal mining or CBM production areas.

Numerous boreholes drilled in the PRB to evaluate uranium potential were not properly plugged. Many boreholes of unknown origin also occur. Uncased boreholes and faulty well casing or plugging could allow methane, if present, to move through the formations penetrated. Migration of methane could be enhanced where these boreholes are located near coal mining or CBM production areas.

106

Other areas with potential for migration or seepage include areas where faults, fractures, or sandstone layers occur in an orientation that provides a conduit for methane movement. The migration of methane could be enhanced where sandstone layers are in contact with the coal zone, or faults and fractures extend from the coal zone into surrounding rocks.

Methane seepage occurring within the active burn area of a coal fire may enhance the intensity of the combustion or prolong the burn. Alternatively, methane seepage might actually make a fire less intense because the methane would be competing with the coal for oxygen in a combustion setting.

Methane would be controlled through BLM-mandated APD conditions of approval addressing well control, casing, ventilation, and plugging procedures appropriate to site-specific CBM development plans.

Spontaneous Combustion of Coal

Development of CBM is not likely to increase the occurrence of coal fires in the Project Area. Most development of CBM in the Project Area, including most development proposed under Alternative 1, is occurring or would occur under confined conditions in the coal aquifer, which are not associated with spontaneous combustion of coals. The partial removal of water during development of CBM depressurizes the coal seam and reduces hydraulic head, but is not likely to leave the coal seam in a condition where oxygen would replace water and result in spontaneous combustion. Although the coals in the PRB contain reactive materials required for combustion and fluctuations in the water table may release the heat of wetting, the supply of oxygen is not sufficient to support combustion (Coates and Heffern 1999).

The coal zone contains less water along the margins of the PRB where surface coal mining and development of CBM are occurring and substantial dewatering has caused or is causing changes in the water table. However, the likelihood that the buried coal seam being developed for CBM would have any increased exposure to oxygen or any increased risk of spontaneous combustion is remote. Although clinker can be found as far as several hundred feet back into the hillside from where it is apparent at the surface (Heffern and Coates 1997), the supply of oxygen would not be sufficient to support combustion at vertical depths of 350 feet and more below the surface where CBM is being developed.

The conditions established and maintained in CBM wells during drilling and after well completion to meet health and safety requirements and optimize gas production create unfavorable conditions for spontaneous combustion of coal. Well bore conditions are controlled to ensure airflow out of the well, to flush fines from the well, and to vent heat at the surface (Lyman and Volkmer 2001).

Alternative 2

Effects associated with geologic hazards likely would be similar to Alternative 1.

67

Alternative 3

Under Alternative 3, additional development of federal leases (other than federal protective wells in drainage situations) would not be authorized once existing authorizations under the Wyodak CBM Project EIS and the Wyodak Drainage CBM EA have been exhausted. Effects associated with geologic hazards likely would be similar to those described under Alternative 1, although oil or gas development of fee and state leases under Alternative 3 would involve far fewer federal undertakings than Alternatives 1 or 2, and less federal control of CBM development activities in geologic hazard areas.

Soils

Effects to soils would be primarily associated with the construction of roads, well pads, water pipelines, gas pipelines, water handling facilities, compressors, production facilities, and electric lines. Disturbances related to the burial of pipelines and electric lines would not occur in the long term, because the trenches would be reclaimed when burial is complete. In addition, because most of each well pad would not be needed for production, most of the disturbance associated with the construction of well pads would be short term.

Effects to soils result from the clearing vegetation; excavating, stockpiling, compacting, and redistributing soils during construction and reclamation; and storing or discharging produced CBM water. Loss of vegetation would expose soils and could result in a loss of organic matter in the soil. Excavation for facility pads and roads could cause slope steepening in cut and fill areas, mixing of soil layers, and breakdown of the soil structure. Removal and stockpiling of soils for reclamation could result in mixing of soil profiles and a loss of soil structure. Compaction of the soil could decrease pore space and cause a loss of soil structure as well. Depending on the infiltration rates, storage or discharge of produced water could alter the physical and chemical properties of soils. All these effects could alter the soil's resistance to water and wind erosion and response to reclamation.

Although the discussions in this section are adequate for a general level of analysis, they are insufficient for use in locating specific well pads, access roads, pipelines, and other associated facilities. Site-specific analysis, typically conducted during the APD and NPDES permit process, would identify specific soil concerns and appropriate mitigation measures. The Buffalo Field Office Coal Bed Methane Well APD and Project Planning Guide (October 2000) provides guidelines for this analysis. As a condition of approval, BLM has required companies to provide copies of water quality monitoring reports submitted to WDEQ.

Alternative 1

Overall, implementation of this alternative would disturb almost 202,400 acres of soils (193,589 acres for CBM facilities and 8,800 acres for non-CBM facilities), which is almost 2.6 percent of the Project Area. Almost 175,400 acres of soils would be affected in the short term to construct facilities to extract and transport CBM and non-CBM resources. Another 27,000 acres would be disturbed for the construction of facilities to handle produced water. In contrast, about 93,400 acres of soils, or 1.2 percent of the Project Area, would be affected in the

108

BEST COPY AVAILABLE

long term for CBM and non-CBM facilities. These disturbances would occur on 23 of the 59 soil series that exist in the Project Area. Only soils that would be disturbed by the alternatives are discussed in this analysis. Together, these soil series make up 75 percent of the Project Area. Table 4–14 shows the distribution of disturbances resulting from CBM and non-CBM facilities by sub-watershed and soil type, and Table 4–15 lists the disturbance for each type of hazard.

Wind Erosion Hazard

Wind erosion is a concern with soil series WY124, WY126, WY207, WY209, and WY211 located in central and western Converse County and extending from south of Gillette to the Montana-Wyoming state line in Campbell County (Figure 4–43). These series all have one or more major constituent that is a fine sand or sandy loam that can easily be picked up and spread by wind (Appendix E). Approximately 21,482 acres of soils with high potential for wind erosion would be disturbed in the short term and 8,298 acres would be disturbed in the long term.

Construction where vegetation is removed and the soil is exposed and broken up present the greatest threat to soils with potential for wind erosion. These activities include cut and fills associated with pad and roads, trenching for pipeline burial, and excavation for reservoirs. COAs would be followed to control wind erosion by limiting the removal of vegetation, avoiding construction on steep slopes and erosive areas, revegetation or covering any topsoil that was removed and stockpiled, surfacing roads and pads, and timely reclamation would minimize both short-term and long-term effects.

Slope Hazards

Although the Project Area contains a large range of slopes (Figure 3–8), all wells, roads and production facilities would be located on gentle to moderate slopes to minimize construction costs and erosion hazards. These locations would reduce the potential for water and wind erosion by reducing steep slopes and surface disturbance associated with large cuts and fills.

The slope ranges and figures used for this analysis are general, and some wells may be located on more severe slopes than currently are shown on Figure 3–8. Specific facility locations and roadways should be assessed for slope and any related erosion hazards and soil instabilities. Steep slopes should be avoided where possible, especially on soils that are susceptible to erosion. On gentle to moderate slopes, soil loss caused by wind and water erosion could be effectively controlled by following the COAs.

Water Erosion Hazards

Water erosion is a concern with soil series WY049, WY050, WY051, WY065, WY066, WY206, WY208, WY209, WY210 and WY211 located in eastern Sheridan County, northern and western Campbell County, throughout Converse County and in Johnson County along the Interstate 25 corridor to Buffalo, and along the Powder River (Figure 4–43). These series all include one or more major constituents that have low permeability and high K-factors, making them susceptible to water erosion (Appendix E). Approximately 57,530 acres in the short term and 21,392 acres in the long term would be disturbed on soils with a high potential for water erosion.

Table 4-14 Disturbance of Soils by CBM and Non-CBM Facilities by Sub-watershed and Soil Series

Sub-watershed	Soil Series	Disturbance[1] (acres)			
		Alternatives 1, 2A, 2B		Alternative 3	
		Short term	Long term	Short term	Long term
Antelope	WY125	8	7	6	5
	WY129	10,632	3,761	4,224	1,490
	WY130	21,119	7,462	7,550	2,664
	WY206	569	214	77	27
	WY207	325	149	179	75
	WY208	1,345	477	105	38
	WY209	2,580	923	1,218	432
	WY210	998	353	208	74
	WY211	991	355	257	90
	WY315	8	7	0	0
	Total	38,576	13,709	13,823	4,895
Clear Creek	WY048	1,426	490	1,346	460
	WY049	6,041	2,194	3,306	1,213
	WY060	3	2	3	2
	WY063	11	9	8	7
	WY065	2,680	932	1,963	683
	WY066	1,504	510	1,311	442
	WYW	88	31	88	31
	WY082	72	25	65	23
	Total	11,825	4,195	8,088	2,861
Crazy Woman Creek	WY048	627	216	420	142
	WY049	2,445	866	1,024	359
	WY050	928	316	71	25
	WY060	6	5	3	2
	WY063	3	2	3	2
	WY065	2,413	833	543	190
	WY066	5	2	5	2
	WY082	4,951	1,750	1,662	584
	WY087	3	2	0	0
	Total	11,379	3,991	3,729	1,306
Dry Fork Cheyenne	WY203	3	2	3	2
	WY204	22	19	8	7
	WY205	3	2	0	0
	WY206	14	12	3	2
	WY207	14	12	6	5
	WY208	6	5	0	0
	WY209	36	31	14	12
	WY210	28	24	11	9
	WY211	11	9	0	0
	Total	135	115	44	38
Lightning Creek	WY204	25	21	17	14
	WY209	74	63	36	31
	WY210	19	16	14	12
	WY211	17	14	3	2
	Total	135	115	69	59
Little Bighorn	WY057	14	12	14	12
	Total	14	12	14	12

Table 4-14 Disturbance of Soils by CBM and Non-CBM Facilities by Sub-watershed and Soil Series

Sub-watershed	Soil Series	Disturbance[1] (acres)			
		Alternatives 1, 2A, 2B		Alternative 3	
		Short term	Long term	Short term	Long term
Little Missouri	WY002	11	9	3	2
	WY050	14	12	3	2
	WY053	234	200	85	73
	Total	259	221	91	78
Little Powder	WY002	22	19	6	5
	WY042	6	5	6	5
	WY043	8	7	0	0
	WY044	6	5	3	2
	WY045	47	40	19	16
	WY046	39	33	22	19
	WY047	259	221	146	125
	WY050	2,723	1,517	792	433
	WY053	1,469	1,255	564	482
	WY124	1,012	483	406	196
	WY125	3,637	1,317	1,255	450
	WY126	5,321	1,919	3,564	1,294
	WY127	2,044	1,150	880	428
	Total	16,591	7,970	7,661	3,454
Middle Fork Powder	WY048	6	5	3	2
	WY059	25	21	3	2
	WY081	6	5	3	2
	WY084	8	7	6	5
	WY085	3	2	3	2
	WY086	6	5	3	2
	WY088	14	12	3	2
	Total	66	56	22	19
Middle North Platte Casper	WY204	6	5	0	0
	WY205	33	28	17	14
	WY207	14	12	6	5
	WY208	22	19	3	2
	WY209	25	21	19	16
	WY321	6	5	3	2
	Total	105	89	47	40
Middle Powder	WY046	80	68	25	21
	WY048	7	4	0	0
	WY049	776	333	62	23
	WY050	1,560	587	196	81
	WY124	800	348	268	124
	Total	3,224	1,340	550	249
North Fork Powder	WY059	3	2	0	0
	Total	3	2	0	0
Salt Creek	WY050	668	238	315	112
	WY082	438	145	231	77
	WY085	6	5	0	0
	WY086	33	28	11	9
	WY208	6	5	0	0
	WY211	8	7	0	0
	WY315	3	2	3	2
	WY317	8	7	6	5
	Total	1,169	437	565	205

Table 4-14 Disturbance of Soils by CBM and Non-CBM Facilities by Sub-watershed and Soil Series

Sub-watershed	Soil Series	Disturbance[1] (acres)			
		Alternatives 1, 2A, 2B		Alternative 3	
		Short term	Long term	Short term	Long term
South Fork Powder	WY084	8	7	8	7
	Total	8	7	8	7
Upper Belle Fourche	WY004	502	198	356	141
	WY053	198	169	165	141
	WY115	6	5	6	5
	WY126	7,587	2,977	5,517	2,163
	WY127	1,117	614	726	315
	WY128	540	203	368	138
	WY129	2,983	1,091	1,830	680
	WY130	11,481	4,236	5,677	2,106
	Total	24,414	9,492	14,645	5,689
Upper Cheyenne	WY004	8	7	8	7
	WY115	11	9	0	0
	WY127	11	9	0	0
	WY129	2,977	1,135	1,350	522
	WY130	157	62	77	31
	WY206	23	16	0	0
	Total	3,188	1,239	1,434	560
Upper Powder River	WY048	2,579	942	1,381	500
	WY049	2,934	1,049	1,057	376
	WY050	20,283	7,370	3,274	1,201
	WY051	616	216	306	107
	WY082	7,755	2,836	1,860	692
	WY124	1,925	706	582	213
	WY125	6,482	2,359	993	364
	WY126	731	260	507	179
	WY128	11,029	4,009	2,430	904
	WY130	1,588	579	811	295
	WY209	11	9	3	2
	WY315	3	2	0	0
	Total	55,938	20,338	13,204	4,834
Upper Tongue River	WY049	3,196	1,144	2,507	885
	WY051	182	66	162	59
	WY055	1,330	498	1,309	488
	WY056	6	5	6	5
	WY057	6	5	6	5
	WY060	3	2	3	2
	WY063	3	2	3	2
	WY064	927	335	838	303
	WY065	1,770	638	1,741	627
	WY066	33	13	28	11
	Total	7,455	2,708	6,600	2,388
Total		174,481	66,036	70,594	26,693

Note:

1. Figures do not include the disturbances for water handling facilities or CMFs, which were not site-specifically located in the GIS database. These facilities would encompass 27,912 acres for Alternative 1, 37,166 acres for Alternative 2A, 33,556 acres for Alternative 2B, and 12,039 acres for Alternative 3.

Table 4–15 Disturbance by Sub-watershed and Hazard

		Disturbance[1] (acres)					
		Alternative 1		Alternative 2A		Alternative 2B	
Sub-watershed	Hazard	Short term	Long term	Short term	Long term	Short term	Long term
Antelope	Wind Erosion	3,896	1,427	3,896	1,427	3,896	1,427
	Water Erosion	6,483	2,322	6,483	2,322	6,483	2,322
	Compaction	34,094	12,053	34,904	12,053	34,904	12,053
	Salinity	None	None	None	None	None	None
	Poor Revegetation	6,816	2,471	6,816	2,471	6,816	2,471
	Prime Agricultural	26,367	9,364	26,367	9,364	26,367	9,364
Clear Creek	Wind Erosion	None	None	None	None	None	None
	Water Erosion	10,234	3,639	10,234	3,639	10,234	3,639
	Compaction	6,134	2,227	6,134	2,227	6,143	2,227
	Salinity	None	None	None	None	None	None
	Poor Revegetation	10,322	3,670	10,322	3,670	10,322	3,670
	Prime Agricultural	11,660	4,129	11,660	4,129	11,660	4,129
Crazy Woman Creek	Wind Erosion	None	None	None	None	None	None
	Water Erosion	5,786	2,015	5,786	2,015	5,786	2,015
	Compaction	7,391	2,614	7,391	2,614	7,391	2,614
	Salinity	None	None	None	None	None	None
	Poor Revegetation	10,737	3,765	10,737	3,765	10,737	3,765
	Prime Agricultural	5,485	1,915	5,485	1,915	5,485	1,915
Dry Fork Cheyenne	Wind Erosion	61	52	61	52	61	52
	Water Erosion	95	81	95	81	95	81
	Compaction	34	29	34	29	34	29
	Salinity	None	None	None	None	None	None
	Poor Revegetation	109	93	109	93	109	93
	Prime Agricultural	84	72	84	72	84	72
Lightning Creek	Wind Erosion	91	77	92	77	91	77
	Water Erosion	110	93	110	93	110	93
	Compaction	19	16	19	16	19	16
	Salinity	None	None	None	None	None	None
	Poor Revegetation	110	93	110	93	110	939
	Prime Agricultural	93	79	93	79	93	79
Little Bighorn	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards
Little Missouri	Wind Erosion	None	None	None	None	None	None
	Water Erosion	14	12	14	12	14	12
	Compaction	None	None	None	None	None	None
	Salinity	None	None	None	None	None	None
	Poor Revegetation	14	12	14	12	14	12
	Prime Agricultural	None	None	None	None	None	None
Little Powder	Wind Erosion	6,333	2,402	6,333	2,402	6,333	2,402
	Water Erosion	2,723	1,517	2,723	1,517	2,723	1,517
	Compaction	1,012	483	1,012	483	1,012	483
	Salinity	None	None	None	None	None	None
	Poor Revegetation	8,404	3,984	8,404	3,984	8,404	3,984
	Prime Agricultural	6,333	2,402	6,333	2,402	6,333	2,402
Middle Fork Powder	Wind Erosion	None	None	None	None	None	None
	Water Erosion	None	None	None	None	None	None
	Compaction	None	None	None	None	None	None
	Salinity	None	None	None	None	None	None
	Poor Revegetation	None	None	None	None	None	None
	Prime Agricultural	6	5	6	5	6	5
Middle North Platte Casper	Wind Erosion	39	33	39	33	39	33
	Water Erosion	47	40	47	40	47	40
	Compaction	22	19	22	19	22	19
	Salinity	None	None	None	None	None	None
	Poor Revegetation	61	52	61	52	61	52
	Prime Agricultural	61	52	61	52	61	52

Table 4–15 Disturbance by Sub-watershed and Hazard

		Disturbance[1] (acres)					
		Alternative 1		Alternative 2A		Alternative 2B	
Sub-watershed	Hazard	Short term	Long term	Short term	Long term	Short term	Long term
Middle Powder	Wind Erosion	800	348	800	348	800	348
	Water Erosion	2,336	920	2,336	920	2,336	920
	Compaction	1,576	681	1,576	681	1,576	681
	Salinity	None	None	None	None	None	None
	Poor Revegetation	2,336	920	2,336	920	2,336	920
	Prime Agricultural	1,583	685	1,583	685	1,583	685
North Fork Powder	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards
Salt Creek	Wind Erosion	8	7	8	7	8	7
	Water Erosion	682	250	682	250	682	250
	Compaction	444	150	444	150	444	150
	Salinity	8	7	8	7	8	7
	Poor Revegetation	1,120	395	1,120	395	1,120	395
	Prime Agricultural	14	12	14	12	14	12
South Fork Powder	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards	No Hazards
Upper Belle Fourche	Wind Erosion	7,587	2,977	7,587	2,977	7,587	2,977
	Water Erosion	None	None	None	None	None	None
	Compaction	15,506	5,728	15,506	5,728	15,506	5,728
	Salinity	508	203	508	203	508	203
	Poor Revegetation	1,117	614	1,117	614	1,117	614
	Prime Agricultural	19,570	7,411	19,570	7,411	192570	7,411
Upper Cheyenne	Wind Erosion	None	None	None	None	None	None
	Water Erosion	None	None	None	None	None	None
	Compaction	3,142	1,204	3,142	1,204	3,142	1,204
	Salinity	19	16	19	16	19	16
	Poor Revegetation	34	25	34	25	34	25
	Prime Agricultural	165	69	165	69	165	69
Upper Powder River	Wind Erosion	2,667	975	2,667	975	2,667	975
	Water Erosion	23,844	8,644	23,884	8,644	23,844	8,644
	Compaction	25,847	9,395	25,847	9,395	25,847	9,395
	Salinity	3	2	3	2	3	2
	Poor Revegetation	37,465	13,623	37,465	13,623	37,465	13,623
	Prime Agricultural	10,384	3,761	10,384	3,761	10,384	3,761
Upper Tongue River	Wind Erosion	None	None	None	None	None	None
	Water Erosion	5,176	1,859	5,176	1,859	5,176	1,859
	Compaction	4,305	1,545	4,305	1,545	4,305	1,545
	Salinity	538	228	538	228	538	228
	Poor Revegetation	4,994	1,793	4,994	1,793	4,994	1,793
	Prime Agricultural	7,433	2,692	7,433	2,692	7,433	2,692

Note:

1. Figures do not include the disturbances for water handling facilities or CMFs, which were not site-specifically located in the GIS database. These facilities would encompass 27,912 acres for Alternative 1, 37,166 acres for Alternative 2A, 33,556 acres for Alternative 2B, and 12,039 acres for Alternative 3.

114

Construction and operation could increase soil loss through water erosion. Removal of vegetation for any activity exposes soils to increased water erosion. Excavation associated with construction of pads, roads and reservoirs could steepen slopes and break down soil aggregates, increasing runoff and gully formation. Pipeline trenches could change erosion patterns if soils settle in the backfilled trench after reclamation and form gullies. Compaction of the soils in pads, roads, and reservoirs could decrease infiltration, promoting high runoff. Any water handling method that would release produced water to the surrounding area could increase water erosion. However, increased availability of water would also increase vegetation, partially mitigating any erosive effects.

The Revised Universal Soil Loss Equation (RUSLE) was used to compute soil loss caused by raindrop splash and runoff (Renard et al. 1997). Estimates were calculated using three conditions: (1) undisturbed (existing rangeland condition); (2) construction (during construction and before reclamation); and (3) reclaimed (1 year after reclamation, assuming 40 percent vegetative cover). The assumption of 40 percent vegetative cover 1 year after reclamation was based on information used for soil loss calculations on CBM projects in the region (BLM 1999a-d). To simplify calculations, all factors, except for K, were assumed to be consistent throughout the Project Area, even though soil loss would be variable. The highest and lowest K factors for the 23 disturbed soils were used to estimate the maximum and minimum soil loss in the Project Area. For the undisturbed condition, estimates of soil loss ranged from 0.1 to 0.6 tons/acre/year. During construction, estimates of soil loss ranged from 3.4 to 18.7 tons/acre/year. One year after reclamation, estimates of soil loss ranged from 0.5 to 2.6 tons/acre/year. These calculations were based on slopes 400 feet long with a gradient of 3 percent on undisturbed ground.

RUSLE calculations were used to estimate increases in loss of soils on disturbed land because of overland flow. Water erosion in drainages downstream from CBM activities caused by runoff from the release of produced water could increase but cannot be accurately predicted using RUSLE. A more detailed description of erosive effects to drainages is contained in the discussion of surface drainages in the section on surface water.

Soil loss would likely increase substantially in the short term after disturbance until reclamation measures became effective in controlling runoff. In addition, soil loss during construction would exceed acceptable levels for all of the soil series disturbed in the Project Area (NRCS 1971 through 1997). These potential effects point to a need for adoption of COAs during the life of the project.

Soil loss can be reduced substantially by avoiding highly erosive areas such as badlands, steep-walled drainages, blowout areas, and other areas subject to active headward erosion (BLM 1999d). Locating roads and pads in areas where cuts and fills would not be required, surfacing of roads and pads, installing drainage controls, and reseeding and installing water bars across reclaimed areas would also aid in reducing soil loss. Pipeline trenches should be mounded when backfilled to prevent soil settling and forming gullies. Similar COAs have resulted in little accelerated erosion and a high level of reclamation success on the Marquiss Project, located south of Gillette (BLM 1999a).

15

Sedimentation

Sedimentation in streams and rivers in the Project Area is an important result of soil loss, but cannot be adequately estimated simply by calculating soil loss. The movement of eroded soil materials to drainages can be blocked or facilitated by relief, climate, vegetation, and bedrock geology. As a result of these characteristics, there is a large difference between soil loss and sediment flow. Sedimentation would be variable throughout the Project Area, but in drainage basins with areas of more than 100 square miles, generally only 10 percent of soil loss would remain in the water flow at the point of exit from the sub-watersheds (Blatt et al. 1972). The remaining 90 percent would never reach flowing water or be deposited in the streambeds of the watershed. Sedimentation in the affected sub-watersheds also depends on the velocity of surface water flow and the volume of water in the stream channels. Discharge of CBM water would increase the natural flow rates and increase the volume of water in the stream channels, which would disperse eroded soil that has been deposited on streambeds, increasing the turbidity of the water and transporting sediment downstream. Predicted flow rates are discussed in the section on Surface Drainages of the Surface Water section by the main drainage in each watershed (Tables 4–3 through 4–13).

Government soil experts state that SAR values of only 13 or more cause potentially irreversible changes to soil structure, especially in clayey soil types, that reduce permeability for infiltration of rainfall and surface water flows, restrict root growth, limit permeability of gases and moisture, and make tillage difficult (Seelig 2000; U.S. Salinity Laboratory Staff 1954). Approximately 50 percent of the predicted average sodium absorption ratios for the 10 affected sub-watersheds exceed 13, with the highest values predicted for the Clear Creek (29) and the Upper Tongue River (39) sub-watersheds (Tables 4–7 and 4–10). Reduced infiltration rates and the formation of an impermeable soil surface in areas high clay soil content over large expanses of uplands areas would greatly increase the contribution of surface runoff to already abnormal in-channel stream flows, thus exacerbating related effects previously mentioned in this section. Additional information on the effects of an increased sodium absorption ratio on soils, agricultural crops, wetland and riparian vegetation, and native upland vegetation can be found in the corresponding sections.

Sedimentation deposition could alter water quality and the fluvial characteristics of drainages in the Project Area and point to a need for COAs associated with water erosion to control sedimentation. Water in the drainages should be monitored for high levels of TDS as well. The section on surface drainages also contains information on the effects of sedimentation on drainages.

Compaction/Shrink-Swell Potential

Compaction and shrink-swell potential is a concern with soil series WY004, WY049, WY051, WY064, WY082, WY124, WY128, WY129, WY130, WY208, and WY210, located throughout Campbell and Converse counties and eastern Sheridan and Johnson counties (Figure 4–43). These series all include one or more major constituents that include very compactable clay loams (Appendix E). Approximately 99,504 acres in the short term and 36,144 acres in the long term would be disturbed on compactible soil. Clay grains are extremely small and can be forced so closely together that few pore spaces remain. Thus, most air and water is pushed out of the soil and plant roots would be unable to penetrate the soil. The composition of the clay soils plays an even more important role, however, in determining compaction and shrink-swell potential than can clay particle size. For example, the mudstones of the Wasatch and Fort Union formations contain montmorillonite (smectite or bentonite) and mixed-layer clays, which expand and contract depending on the introduction or deletion of oxygen and hydrogen (Devine 2002). Because of the absence of air and water and the difficulty of root growth, reclamation of a tightly compacted clay soil can be difficult. Compacted soils also have low permeability, and runoff is high, adding to water erosion.

Activity on well pads, production facilities and roads, and storage of water in reservoirs has the potential to compact soils. COAs would minimize both short- and long-term effects. Pad and road construction and traffic on highly compactable soils should be minimized wherever possible, and soils should be loosened for reseeding during reclamation. COAs to reduce water erosion should be employed on compactible soils in light of the high potential for runoff.

Salinity

Soil series WY004, WY115, WY316, WY317, and WY325 are listed by the NRCS's Soil Surveys (NRCS 1971 through 1997) as high in salinity (Appendix E). Approximately 538 acres in the short term and 228 acres in the long term would be disturbed on this soil. This statement is misleading, as the salinity and sodicity of soils, like most chemical characteristics, are highly variable and can change drastically over a few feet. Any soil in the Project Area can be saline or sodic, depending on site-specific soil conditions, such as permeability, sodium content, clay content, the quality of nearby surface water, plant species, and drainage characteristics. Decisions on the locations of water disposal facilities that could affect soil salinity and other chemical levels should be based on these parameters.

Because of the variable nature of produced water and differing characteristics of soils in the Project Area, water handling options could have significant effects on soils. Five water handling options are included under Alternative 1: injection; surface discharge (including infiltration and irrigation); infiltration reservoirs; containment reservoirs; and LAD. Injection would affect soils in the Project Area the least, and its effects would be similar to CBM well construction and production. After injection, containment would introduce the least amount of produced water to the surrounding soils. These reservoirs could be lined with low-permeability geotextiles, synthetic or clay liners, or compacted to prevent produced water from inundating the soils below. Because of the large size of the reservoirs, compaction is the most reasonable method to reduce infiltration. Locating containment reservoirs on compactable soils where infiltration would be 10 percent or less would also help to reduce effects on soils. Soils below these reservoirs would be affected by compaction and infiltration. COAs should be followed during construction of reservoirs to prevent erosion. Even with COAs, reclamation would be difficult based on the size of the area, the amount of soil moved, the concentrated compaction below the reservoir, and the material that would remain after the produced water has evaporated. Lining the infiltration reservoir could be followed by removing or covering the contained evaporite with a medium suitable for plant growth and diversion of surface flow away from the solid waste.

Surface discharge (including infiltration and irrigation), infiltration reservoirs, and LAD would introduce the most produced water to the surrounding soils. Because of the deleterious effect of water high in SAR on soil productivity and reclamation potential, care should be taken that produced water is not discharged near or applied to highly saline soils. The sodium capacity of each soil should be known, application should be halted when capacity is reached, and the soil should be reclaimed. Halting the application of produced water to reclaim the soil would be much more difficult in the reservoirs than under LAD or surface discharge. *General Guidance for Land Application of CBM Produced Water* should be followed to mitigate effects to soils (Appendix E).

Suitability for irrigation depends on interaction of soil types, SAR values, salinity values, and crops grown. The decision to use produced water for irrigation should be made on a site-by-site basis. CBM produced water in the Project Area is expected to range in EC from 599 µS/cm to 3,129 µS/cm and SAR from 6.4 to 38.7. Irrigation water, which would be a mix of both CBM produced water and current stream water, is expected to range from 537 µS/cm to 597 µS/cm for EC and 1.81 to 22.2 for SAR. The highest EC and SAR values would occur in the Salt Creek watershed (see the section on Surface Water). A portion of water used to irrigate soils for crop production must be used to leach salts in the soil water to below the rooting zone (typically 1 to 1.5 meters). The percentage of water used to leach soils in relation to the total amount of water applied for irrigation is referred to as the leaching fraction. The salinity of the irrigation water and the leaching factor together determine the effects of salinity in the soil water, which is the critical factor in the effects to crop yields. Irrigation with high-quality water for a few years would result in buildup of salinity in soils with low permeability and, thus, would restrict internal drainage. Water high in SAR can compound this effect by reducing further the infiltration and permeability of soils, limiting the ability to leach salts from the root zones (Munn 2002b). The salinity of the water in soil could eventually equilibrate with the salinity of the irrigation water as a result of continuous irrigation (EPA 2002b).

Average values have been predicted in the section on Groundwater for the quality of the proposed discharges of CBM produced water in each of the 10 subwatersheds that would be affected by the project. Predicted average electrical conductivity values range from 599 µS/cm for the Upper Cheyenne River subwatershed to 3,129 µS/cm for the Crazy Woman River sub-watershed. Predicted SAR values range from 6.4 for the Upper Cheyenne River sub-watershed to 38.7 for the Upper Tongue River Watershed.

No numeric water quality standards are designated for SAR and salinity in the State of Wyoming. General SAR and salinity thresholds can, however, be estimated for protection of irrigated soils or soils where land application of produced water is planned. These thresholds would be based on available information on the effects of high SAR and salinity on soil chemistry, soil structure, and published SAR and TDS tolerance levels for various vegetative species. Estimated allowable SAR and salinity thresholds are complicated by the relationship between SAR and salinity and by the direct toxicity of sodium and salinity to cer-

118

tain crops and native vegetation. For example, the effects of sodium-induced changes in soil structure caused by high SAR become less severe as the salinity level in soil water increases. Initially, these changes might promote the concept of artificially enhancing the salinity of irrigation water to counter CBM discharge water that is high in SAR; however, the effects of the increased salinity could in turn be toxic to the plants that grow in the soil. The sections on Land Use and Vegetation discuss the tolerance of native vegetation and agricultural crops to SAR and salinity. Soil type would also be factored into the establishment of SAR and salinity thresholds. Leaching is an important factor in reducing the effects of salinity on crop production, but soils high in clay are restricted in their permeability and ability to be leached. Montmorillonite clays, which are common in the river basins that could be affected by CBM activity, are especially sensitive to the destructive effects on soil structure of high SAR. Direct toxicity of the sodium ion to certain plants is an additional factor that makes it necessary to establish upper limits to both SAR and salinity, creating paired SAR and salinity thresholds (EPA 2002b). Table 4–16 shows guidelines that could be used for establishing SAR and salinity (ECw) limits for irrigation water. The guidelines are based on a study of the quality of irrigation water by Hergert and Knudsen (1997). Several other studies have approached the topic of setting EC and SAR limits for irrigation water, including studies by Ayers and Westcot (1985) and Horpestad (2001).

Undesired consequences could also occur should produced water from CBM wells be discharged at points within closed basins. Water discharged within a closed basin would drain to the low point of the basin or playa. The sustained release of produced water from CBM wells could accumulate in closed basins as water is evaporated, leaving its dissolved minerals, such as sodium, behind as solids. In addition, regardless of the salinity levels in the inflows and playa soils, the long-term ponding of playa bottoms would alter the normally dry soil or playa bottom conditions and would result in changes in soil conditions (BLM 1999c).

Table 4–16 Guidelines for Determination of Water Quality Thresholds for Irrigation

SAR Hazard	Salinity Hazard, ECw (millimhos/cm)				Expected Soil Permeability and Management
	Low, 0.75	Medium, 0.75–1.50	High, 1.50–3.00	Very High, >3.00	
	SAR Ranges				
Low	< 6	< 6	< 4	< 2	No permeability problems expected.
Medium	6 – 9	6 – 8	4 – 6	2 – 4	Usually no permeability problems expected except when soils are high in clay and ECw is high or very high.
High	9 – 12	8 – 10	6 – 8	4 – 6	Possible permeability problems. Can use on sandy soils if LR is met. May need soluble calcium added if silt loam or finer texture. Monitor by soil test.
Very High	>12	>10	>8	>6	Serious permeability problems expected. Requires added soluble calcium or use only limited amounts as supplement to rain fall or good quality water. Monitor with soil test at the end of each season.

Source: Adapted from Hergert, et al. 1997

The development of saline and wet soil could be minimized by avoiding discharge in or upstream from areas where water could become concentrated in the soils or where soils are already saline. Even with these practices, water quality and soils in the Project Area should be monitored for high salinity and SAR levels.

Effects similar to those described in closed basins could occur in infiltration reservoirs. Avoiding constructing infiltration reservoirs on highly saline areas would reduce the effects to soils. Locating reservoirs on areas where water could easily move through the soils, such as soils with low potential for compaction, high permeability, and porous bedrock, would reduce the potential for saturation of the soil. Another avoidance approach would either treat or amend the CBM water before it enters the infiltration reservoirs through dilution with precipitation water or the introduction of soluble sources of calcium (such as gypsum) or sulfuric acid (which reacts with the calcium carbonate already in the soil to form gypsum). The first method of dilution is not reliable, especially given the prolonged and intermittent drought period common in this region, and the latter two methods increase the amount or solubility of soil-borne salts.

Reclamation of saline soils can be difficult, and no method that works in all situations has yet been found. Possible methods include raising salt-resistant crops and repeatedly flooding the affected area with water low in SAR to remove salts from the rooting zone. The success of these methods would depend on soil types, salinity values, and drainage characteristics of the area. Leaching may only be effective for a short period, as diffusion of salts up through the profile would likely occur over time unless the salts were leached into shallow alluvial aquifers. The leaching of amendment salts such as gypsum or the increase in situ soil-borne salts through acidification of the soil profile would increase loading of these constituents to surface and shallow ground water. It is possible to install perforated plastic pipe drains to facilitate removal of salinity from irrigated fields (Munn 2002a).

Mitigation alternatives for sodic soil could include incorporation of soil amendments, including various sources of soluble calcium, to reduce the potential for sodium ion toxicity on plant growth and mitigate the deterioration of soil structure caused by slaking and the swelling and dispersion of clays resulting from excess exchangeable sodium. Amendments could include one or more of the following commercially available materials: $CaSO_4$ (gypsum), $MgSO_4$, $K2SO_4$, CaCl, MgCl, KCl, H_2SO_4 (sulfuric acid), elemental sulfur, organic matter (manure/alfalfa/Biosol), and N-pHuric.

With the exception of sulfuric acid, all amendments could be broadcast by hand or by mechanical spreading. Sulfuric acid could be wet broadcast using appropriate equipment. After the amendment has been applied, the area could be tilled to break up the surface of the soil and, at least partially, incorporate the amendments.

After the sulfuric acid amendments have been incorporated, the area should be left to react for at least 1 week. This amendment produces an exothermic chemical reaction in the soil. This dormant period would allow the soils to react without chemically or thermally damaging the seed. After the reaction period, an appropriate seed mixture could be applied using a drill-seeder or by dry broadcast and light scarification. To revegetate the affected area, plant species with demonstrated tolerances to sodium and salt or an enhanced ability to take up calcium should be selected and seeded. These steps should be followed by leaching with irrigation water according to predicated leaching requirements for the soil and known salt tolerances of the seeded species.

The mitigation measures described above can be applied to rangeland or irrigated fields but are extremely limited by site-specific soil conditions, current precipitation patterns, the cost of implementation, and the practicality of mechanization. Mitigation and monitoring would most likely be required for LAD facilities on a site-specific basis and would be described in detail in the monitoring plans at the permitting level of analysis for each proposed facility.

Poor Revegetation Potential

Poor revegetation potential is a concern with soil series WY049, WY050, WY065, WY066, WY082, WY125, WY127, WY206, WY207, WY208, WY209, WY210, and WY211 located in northern Campbell County, throughout Converse County, east of Interstate-25 in Sheridan County, and in Johnson County along the Interstate-25 corridor to Buffalo, and along the Powder River (Figure 4–43). These series all have capability classes indicating that the soil would respond poorly to reclamation (Appendix E). About 83,639 acres in the short term and 31,510 acres in the long term would be disturbed on soils with poor revegetation potential.

All, hazards previously discussed have a potential effect on revegetation potential. Thus, COAs associated with all other categories in this section would aid in reclamation. Mixing of soil materials during excavation or compaction, especially in the soil series listed above, where one or two dominant soils have poor potential for revegetation could have an effect on reclamation and future productivity. The COAs do not mention avoiding soil mixing, but this mitigation measure is recommended by numerous soil surveys in the area. Soil series WY206 and WY211 should be avoided in areas where the soil is shallow or on steep slopes as all three major soil types in these series have poor revegetation potential.

Prime Agricultural Soils

Prime agricultural soils are found in soil series WY004, WY048, WY049, WY051, WY055, WY064, WY065, WY066, WY124, WY126, WY130, WY207, WY208, WY209, and WY210 located in central Campbell County, throughout Converse and Sheridan Counties, in Johnson County Interstate 25, and along the Powder River (Figure 4–43). These series all have one or more major constituents identified by the Wyoming state office of the NRCS as Prime Agricultural Soils (Appendix E). About 89,238 acres in the short term and 32,643 acres in the long term would be disturbed on Prime Agricultural soils.

All hazards discussed previously have a potential effect on soil productivity. Thus, COAs associated with all other categories in this section would aid in reclamation. Mixing of soils that are not prime agricultural soils with prime agricultural soils during excavation or compaction could affect reclamation and future productivity.

Alternative 2

Alternative 2A

Implemenation of this alternative would disturb almost 212,000 acres of soils (202,843 acres for CBM facilities and 8,800 acres for non-CBM facilities), which would be 2.7 percent of the Project Area. Oil and gas facilities would disturb almost 175,400 acres and facilities to handle water produced from CBM wells would disturb 36,263 acres. Following reclamation of buried facilities and reductions of well pads and other facilities, 102,658 acres would be disturbed over the long term. This disturbance would include 95,138 acres for CBM facilities and 7,520 acres for non-CBM facilities.

Alternative 2A emphasizes the use of infiltration impoundments to dispose of CBM produced water. Surface discharge (and all associated treatments) would be decreased and LAD and containment reservoirs would be increased. The increase in disturbed acreage would correspond to not only a rise in soil loss, but to a change in the type of disturbance as well.

Per acre, reservoirs require much more construction than surface discharge because of the amount of excavation. Reservoirs also cause much deeper soil disturbance, increasing the chance for mixing of soil layers. Based on the amount of excavation and the depth of disturbance, construction of reservoirs would create larger stockpiles of soils, increasing the chance for wind and water erosion. A larger number of reservoirs would also increase compaction of the soils through construction and the weight of the water. Because water discharged to natural drainages would have a much higher infiltration rate than the infiltration and containment reservoirs, infiltration of produced water would be decreased under Alternative 2A. Effects to soils downstream from the Project Area would probably be reduced along with a reduction in surface discharge. Increased LAD would increase the amount of infiltration, but this increase would be offset by a decrease in surface discharge. In all, Alternative 2A would reduce surface discharge and infiltration, but would increase the potential for wind and water erosion, soil mixing, and compaction.

Alternative 2B

Implemenation of this alternative would disturb about 208,000 acres of soils (199,233 acres for CBM facilities and 8,800 acres for non-CBM facilities), which would be 2.6 percent of the Project Area. Oil and gas facilities would disturb almost 175,400 acres and facilities to handle water produced from CBM wells would disturb 32,653 acres. Following reclamation of buried facilities and reductions of well pads and other facilities, 99,048 acres would be disturbed over the long term. This disturbance would include 91,528 acres for CBM facilities and 7,520 acres for non-CBM facilities.

Alternative 3

Implemenation of this alternative would disturb about 82,633 acres of soils (79,052 acres for CBM facilities and 3,581 acres for non-CBM facilities), which would be 1.0 percent of the Project Area. Oil and gas facilities would disturb almost 71,000 acres and facilities to handle water produced from CBM wells would disturb 11,683 acres. Following reclamation of buried facilities and reductions of well pads and other facilities, 38,518 acres would be disturbed over the long term. This disturbance would include 35,458 acres for CBM facilities and 3,060 acres for non-CBM facilities.

Cumulative Effects

Alternative 1

By the end of 2001, approximately 12,024 CBM wells would have been drilled in the Project Area (Figure 4-43). Assuming that all of these wells would be completed and in production by the end of 2001, these wells and their associated facilities would disturb an estimated 35,725 acres in the long term.

Because of the widespread nature of CBM development, concentrated impacts on soils are not likely, except at reservoirs, LAD sites, and pipeline routes. Other resources in the Project Area could be affected by the changes in soils as well. The large amounts of disturbed and stockpiled soils at reservoirs and LAD sites could affect air quality in the area through wind erosion. Additional wildlife and cattle usage around reservoirs would further disturb soils through increased travel and loss of vegetation cover. If trenches were allowed to gully, long pipelines could change drainage patterns in the sub-watersheds. Sedimentation from water erosion could change water quality and fluvial characteristics of streams and rivers in the sub-watersheds of the Project Area. SAR in water in the sub-watersheds could be altered by saline soils because disturbed soils with a conductivity of 16 mmhos/cm could release as much as 0.8 tons/acre/year of sodium (BLM 1999c). Soils in floodplains and streambeds may also be affected by produced water high in SAR and TDS.

In 10 years, the long-term surface disturbances associated with reasonably foreseeable CBM and non-CBM projects may be 85,000 to 95,000 acres for Alternatives 1, 2A, and 2B, and 35,500 acres for Alternative 3. Construction, such as excavation, compaction, and soil mixing, related to mining would affect soils in much the same way as activities related to CBM. In addition to oil and gas, uranium, coal, sand, gravel, and scoria mining occur within the Project Area.

Impacts to agriculture could occur because of the potential effects on prime agricultural soils and water quality in the Project Area. CBM facilities should be located with agricultural concerns in mind, and TDS and SAR should be monitored, especially in water used for irrigation, livestock, and human consumption.

Disturbance related to urban and residential areas and recreation may increase along with increased CBM activity. Recreation, such as hunting and off-roading, could increase with the proliferation of roads from CBM development. Although urban and residential development would likely follow COAs for mitigating effects to soils, recreationists may not. Traffic on CBM roads should be monitored to insure that unnecessary impacts to soils do not occur.

Alternative 2A

The cumulative impacts of Alternative 2A are not expected to vary from those described for Alternative 1.

Alternative 2B

The cumulative impacts of Alternative 2B are not expected to vary from those described for Alternative 1.

Alternative 3

Because of the decreased amount of CBM activity under Alternative 3, all cumulative impacts described for Alternative 1 are expected to decrease, except those related to mineral and energy resource projects.

Landscape Processes

Biodiversity

Project activities that would occur under each alternative have the potential to affect biodiversity in the Project Area. The effects of the proposed project on some of the components of biodiversity, such as vegetation and land cover types, wetlands and riparian areas, terrestrial wildlife, aquatic wildlife, and threatened, endangered, and sensitive species, are discussed below. As indicated in each of the following sections, populations of species or groups of species would be affected, but extirpation of species from the Project Area is not predicted. For this reason, species richness across the Project Area would not change. Species richness may be altered in certain areas of concentrated development if extirpation occurs on a local basis. Beyond species richness, patterns and evenness of species occurrence may change, as may dominant species. This effect is expected to be most noticeable at a local scale, but is not expected to result in substantial changes in biodiversity at a landscape or Project Area scale. Impacts from the proposed project would occur within "conservation sites" defined by the Nature Conservancy (1999) for the Northern Great Plains Steppe Ecoregion, but the effects could not be quantified because the boundaries of the sites are insufficiently defined.

Habitat Fragmentation

Construction and operation of project-related facilities would result in fragmentation of habitats in the Project Area. Fragmentation would occur through loss of narrow strips along roads and small patches at well pads and facility sites. The extent of this fragmentation is substantially different than the type that has been extensively studied in forested habitats because habitat loss would occur as narrow strips and small patches within a largely unaffected matrix as opposed to widespread habitat loss with a few, small remaining patches of unaffected habitat. The effects of habitat fragmentation on individual species or groups of species are discussed in the following sections.

Ecosystem Function

One potential effect of all alternatives would be alteration of disturbance regimes, particularly fire and flooding. Fire regimes may change for several reasons. The frequency of fires may increase because of the greater amount of activity, especially along roads, in the Project Area. Greater activity would increase the potential for human-caused fires. However, expansion of the road network may increase the ability for local fire departments to suppress fires, limiting the spread of fires in areas where access was previously limited. In addition, the increased resource values associated with oil and gas development may result in increased fire suppression to protect these resources.

Flooding may also be affected by the proposed project. Increased base flows in streams from surface discharge would result in decreased channel capacity to accommodate flood flows. Increased base flows would also result in increased riparian and wetland areas, which have capacity to absorb and attenuate flood flows. Each of these changes in ecosystem processes would result in minor alterations to biodiversity and are not expected to substantially alter the form or function of ecosystems in the Project Area.

Vegetation and Land Cover Types

Direct effects to vegetation would occur from ground disturbance caused by construction of well pads, compressor stations, ancillary facilities, associated pipelines, and roads. Short-term effects would occur where vegetated areas are disturbed but later reclaimed within 1 to 3 years of the initial disturbance. Long-term effects would occur where well pads, compressor stations, roads, water-handling facilities, or other semi-permanent facilities result in loss of vegetation and prevent reclamation for the life of the project. These areas would be reclaimed during the abandonment phase. There would be some permanent loss of vegetation for roads and other facilities that are not reclaimed.

Indirect effects to vegetation would occur as a result of project activities other than the direct disturbance or removal of vegetation. Possible indirect effects include: (1) an increase in the potential for the spread of noxious weeds and displacement of native vegetation caused by the increased ground disturbance in the Project Area; (2) alteration of the distribution of types of vegetation caused by changes in volume and rate of surface water flows, particularly changes in stream flow from intermittent to perennial; (3) alteration of ecosystem biodiversity through changes in the composition, abundance, and distribution of plant species; and (4) changes in vegetation types that are important to wildlife species that depend on these types as habitat.

Alternative 1

Direct Effects

Under Alternative 1, direct disturbance would be the primary impact to vegetation resources in the Project Area. Implementation would disturb almost 202,400 acres of vegetation in the Project Area (193,589 acres for CBM facilities and 8,800 acres for non-CBM facilities), which would be 2.6 percent of the area. Approximately 175,400 acres would be directly disturbed in the short term to extract and transport CBM and non-CBM resources. Another 27,000 acres would be disturbed for the construction of facilities to handle water produced from CBM wells. Direct disturbance would occur across all surface ownership types in 13 of the 14 vegetation types within the Project Area. The aspen vegetation type would not be disturbed (Table 4–17). Direct disturbance of vegetation also would occur in each of the 18 sub-watersheds (Table 4–18).

Table 4–17 Short-term Vegetation Disturbance by Surface Owner — Alternatives 1, 2A, and 2B

Vegetation Type	Disturbance[1] (acres)					
	BLM					
	BFO	CFO	FS	State	Private	Total
Agriculture	12	0	3	66	913	994
Aspen	0	0	0	0	0	0
Barren	187	0	3	150	1,555	1,895
Coniferous Forest	91	0	25	65	520	701
Forest Riparian	0	0	0	0	6	6
Herbaceous Riparian	0	3	0	0	0	3
Mixed Grass Prairie	1,159	6	154	1,981	15,891	19,191
Other Shrubland	6	0	0	8	14	28
Sagebrush Shrubland	4,902	11	2,528	3,011	43,174	53,626
Shortgrass Prairie	12,325	17	4,213	5,400	72,423	94,378
Shrubby Riparian	6	0	3	50	218	277
Urban/Disturbed	0	0	0	0	3	3
Water	0	0	0	4	160	164
Wet Meadow	14	0	14	313	2,873	3,214
Total	18,702	37	6,943	11,048	137,750	174,480

Note:
1. Figures do not include the disturbances for water handling facilities or CMFs (903 acres), which were not site-specifically located in the GIS database.

The initial area disturbed during the construction phase is typically larger than is required for the operation phase. After each well and associated roads and other facilities are complete, portions of the disturbed areas would be reclaimed. Long-term disturbance would occur in the same 13 vegetation types as would short-term disturbance, but the total area that remained disturbed would be smaller. Over the long term, CBM and non-CBM facilities constructed under this alternative would affect about 93,400 acres of vegetation, or 1.2 percent of the Project Area. As projected, most of the disturbance would occur on private lands and involve shortgrass prairie and sagebrush shrublands (Table 4–19 and Table 4–20). The areal extent of vegetation that would be permanently lost is not known at this time because the percentage of roads to be left unreclaimed is not yet known. Long-term disturbance would also occur in all 18 sub-watersheds, but again in lesser amounts.

BLANK PAGE

Table 4-18 Short-term Vegetation Disturbance by Sub-watershed — Alternatives 1, 2A, and 2B

	Disturbance[1] (acres)														
Sub-watershed	Agriculture	Aspen	Barren	Coniferous Forest	Forest Riparian	Herbaceous Riparian	Mixed Grass Prairie	Other Shrublands	Sagebrush Shrublands	Shortgrass Prairie	Shrubby Riparian	Urban/Disturbed	Water	Wet Meadow	Total
Little Bighorn River	0	0	0	0	0	0	11	0	3	0	0	0	0	0	14
Upper Tongue River	345	0	63	5	0	0	3,305	0	1,151	1,143	146	0	0	1,292	7,450
Middle Fork Powder River	0	0	0	6	3	0	11	16	11	19	0	0	0	0	66
North Fork Powder River	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
Upper Powder River	24	0	658	192	0	0	4,420	0	16,666	33,783	14	0	0	179	55,936
South Fork Powder River	0	0	0	3	0	0	3	0	0	3	0	0	0	0	9
Salt Creek	0	0	0	63	0	0	0	0	172	935	0	0	0	0	1,170
Crazy Woman Creek	0	0	298	7	0	0	683	3	4,018	6,363	0	0	0	0	11,372
Clear Creek	492	0	108	25	0	0	3,145	3	2,612	3,877	91	0	156	1,325	11,834
Middle Powder River	12	0	19	91	0	0	631	0	977	1,452	3	0	0	39	3,224
Little Powder River	36	0	175	253	0	0	3,564	0	7,119	5,230	17	0	0	196	16,590
Little Missouri River	3	0	0	3	0	0	129	0	72	47	0	0	0	6	260
Antelope Creek	51	0	131	28	0	0	393	0	9,113	28,858	0	0	0	0	38,574
Dry Fork Cheyenne River	3	0	6	0	3	0	52	0	25	47	0	0	0	0	136
Upper Cheyenne River	0	0	20	6	0	0	260	0	1,441	1,461	0	0	0	0	3,188
Lightning Creek	3	0	3	0	0	0	58	6	52	14	0	0	0	0	136
Upper Belle Fourche River	25	0	406	19	0	0	2,465	0	10,161	11,146	6	0	8	177	24,413
Middle North Platte Casper	0	0	8	0	0	3	58	0	33	0	0	3	0	0	105
Total	994	0	1,895	701	6	3	19,191	28	53,626	94,378	277	3	164	3,214	174,480

Note:

[1] Figures do not include the disturbances for water handling facilities or CMFs (903 acres), which were not site-specifically located in the GIS database.

127

BEST COPY AVAILABLE

Table 4–19 Long-term Vegetation Disturbance by Surface Owner — Alternatives 1, 2A, and 2B

Vegetation Type	Disturbance[1] (acres)					
	BLM					
	BFO	CFO	FS	State	Private	Total
Agriculture	7	0	0	25	336	368
Aspen	0	0	0	0	0	0
Barren	79	0	1	54	601	735
Coniferous Forest	52	0	20	37	272	381
Forest Riparian	0	0	0	0	5	5
Herbaceous Riparian	0	2	0	0	0	2
Mixed Grass Prairie	457	5	132	759	6,258	7,611
Other Shrubland	5	0	0	7	12	24
Sagebrush Shrubland	1,842	9	1,054	1,161	16,513	20,579
Shortgrass Prairie	4,560	14	1,569	2,001	26,816	34,960
Shrubby Riparian	4	0	2	20	83	109
Urban/Disturbed	0	0	0	0	2	2
Water	0	0	0	1	57	58
Wet Meadow	6	0	12	114	1,072	1,204
Total	7,012	30	2,790	4,179	52,027	66,038

Note:
1. Figures do not include the disturbances for water handling facilities or CMFs (363 acres), which were not site-specifically located in the GIS database.

p8

Table 4–20 Long-Term Vegetation Disturbance by Sub-watershed — Alternatives 1, 2A, and 2B

	Disturbance[1] (acres)														
Sub-watershed	Agriculture	Aspen	Barren	Coniferous Forest	Forest Riparian	Herbaceous Riparian	Mixed Grass Prairie	Other Shrublands	Sagebrush Shrublands	Shortgrass Prairie	Shrubby Riparian	Urban/Disturbed	Water	Wet Meadow	Total
Little Bighorn River	0	0	0	0	0	0	9	0	2	0	0	0	0	0	11
Upper Tongue River	129	0	23	2	0	0	1,222	0	405	415	54	0	0	458	2,708
Middle Fork Powder River	0	0	0	5	3	0	9	14	9	16	0	0	0	0	56
North Fork Powder River	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Upper Powder River	12	0	243	70	0	0	1,600	0	6,052	12,290	5	0	0	67	20,339
South Fork Powder River	0	0	0	2	0	0	2	0	0	2	0	0	0	0	6
Salt Creek	0	0	0	24	0	0	0	0	74	340	0	0	0	0	438
Crazy Woman Creek	0	0	97	4	0	0	238	3	1,412	2,236	0	0	0	0	3,990
Clear Creek	176	0	39	11	0	0	1,123	2	945	1,337	32	0	55	476	4,196
Middle Powder River	6	0	10	39	0	0	272	0	368	618	2	0	0	26	1,341
Little Powder River	12	0	88	191	0	0	1,668	0	3,380	2,519	10	0	0	103	7,971
Little Missouri River	2	0	0	2	0	0	110	0	61	40	0	0	0	5	220
Antelope Creek	18	0	47	11	0	0	143	0	3,240	10,250	0	0	0	0	13,709
Dry Fork Cheyenne River	2	0	5	0	2	0	45	0	21	40	0	0	0	0	115
Upper Cheyenne River	0	0	8	4	0	0	93	0	564	571	0	0	0	0	1,240
Lightning Creek	2	0	2	0	0	0	49	5	45	12	0	0	0	0	115
Upper Belle Fourche River	9	0	166	16	0	0	977	0	3,973	4,274	6	0	3	69	9,493
Middle North Platte Casper	0	0	7	0	0	2	49	0	28	0	0	2	0	0	88
Total	368	0	735	381	5	2	7,611	24	20,579	34,960	109	2	58	1,204	66,038

Note:

1. Figures do not include the disturbances for water handling facilities or CMFs (363 acres), which were not site-specifically located in the GIS database.

Several options for handling CBM produced waters would be implemented and would result in short- and long-term disturbance to vegetation in the Project Area. Details of the water handling options are discussed in Chapter 2. Water handling would directly disturb vegetation in 10 of the 18 sub-watersheds within the Project Area (Table 2–6 and Table 2–7). The total amount of vegetation disturbed as a result of water handling methods (27,009 acres) for Alternative 1 would be more than that for Alternative 3 because of the greater number of wells, but less than for both Alternatives 2A and 2B, where the same number of wells would be drilled but different water handling methods would be used.

Indirect Effects

Implementation of Alternative 1 would cause indirect effects to vegetation types within the Project Area. After the life of the project, most facilities would be removed and the disturbed areas would be reclaimed and returned to pre-project uses. This restoration would typically include replacing salvaged topsoil, regrading where necessary, reseeding disturbed areas, and controlling noxious weeds. Reclamation of all native vegetation types present in the Project Area, particularly sagebrush shrublands, would be difficult to achieve. Efforts would be continued until reclamation is successful. Replacement of pre-disturbance vegetation communities could be a long-term effort because of the difficulty in replicating native plant communities. Forested areas, shrublands, and even native grasslands would remain in a low-diversity state for an extended period (years to decades) until recruitment of natural plant species re-establishes the pre-disturbance level of diversity.

Perhaps the greatest potential effect of the development of CBM on vegetation in the PRB is the potential import and spread of noxious weeds around project facilities. BLM's primary mission is to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations (BLM 2000c). One sub-category of this mission calls for BLM to restore and maintain the health of the land. As stated in BLM's document *Partners Against Weeds*, one of the greatest obstacles to maintaining healthy ecosystems and restoring impaired ecosystems is the rapid expansion of noxious weeds because these invasive plants can dominate many sites and often cause permanent damage to plant communities (BLM 1996b).

Executive Order 13112 on Invasive Species, issued by the President in February 1999, established the National Invasive Species Council (NISC). Besides promoting multi-jurisdictional cooperation among federal, state, local, and tribal authorities, Executive Order 13112 directed the NISC to provide guidance on invasive species for federal agencies to use in implementing NEPA and to prepare and issue a National Invasive Species Management Plan. The National Invasive Species Management Plan, published in October 2001, provides for the nation an action plan composed of the following topics: leadership and coordination; prevention; early detection and rapid response; control and management; restoration; international cooperation; research; information management; and education and public awareness. Although each of these topics pertains in some degree to the management of invasive species within the Project Area, of particular concern are strategies set forth in the prevention, early detection and rapid response, control and management, restoration, and education and public awareness sections.

The first line of defense and the most cost-effective strategy against invasive species over the long-term is preventing them from becoming established. A critical component of the prevention strategy is the management of pathways to hinder the introduction and spread of invasive species. Common pathways for dispersal of seed include personnel and vehicle travel, sources of gravel and fill, and sources of seed. Management of pathways is the most efficient way to address unintentional introductions (NISC 2001).

When prevention strategies fail to stop establishment of noxious weeds, early detection of invasions and quick and coordinated responses are needed to eradicate or contain invasive species before they become so widespread that control becomes technically and financially impossible (NISC 2001). Effective control and management strategies to prevent spread or lessen effects should be implemented in areas where noxious weeds are currently established. Control and management of invasive species populations are accomplished using an integrated pest management (IPM) approach, which may include strategies for eradication, population suppression, or limiting dispersal of an invasive species within a local area. Selection of an IPM strategy for any particular area depends on the species targeted and known environmental effects of available control methods. Methods of control may include cultural practices such as revegetation plans or grazing management; physical restraints, including fences and sanitation of equipment (washing vehicles and removing seed from clothing); removal mechanisms, such as hand-removal or burning; application of chemical or biopesticides; and release of selective biological control agents. Effective application of IPM often requires coordination of multiple control methods.

Restoration of disturbed areas is an integral component of comprehensive prevention and control programs implemented to keep invasive species from causing greater environmental disturbances (NISC 2001). Construction among severe infestations of noxious weeds may require implementation of IPM strategies that focus on eradication or suppression to inhibit the proliferation of targeted species. Education and outreach programs for all personnel engaged in development of oil and gas constitute an important line of defense for prevention and control of invasive species. Local weed and pest control districts should be consulted during the development of IPM strategies and education programs.

Infestations of noxious weeds cause many negative effects on resources in any given area. Once weeds are introduced into an area, they commonly invade the most productive sites, such as riparian areas and sites with deep, fertile soil. Infestations commonly reduce and sometimes drastically reduce the carrying capacity for livestock. Monocultural stands of one species of weed disrupt the multi-storied structure typical of native plant communities, leading to a reduction or possible elimination of use by wildlife. Recreationists, such as hikers or hunters, may avoid areas of noxious weed infestations for a variety of reasons, including lack of scenic beauty or wildlife or the difficulty associated with negotiating areas covered with stickers or burs.

One of the primary mechanisms for dispersal of the seed of noxious weeds is motor vehicles. Historically, recreational vehicles (motorcycles, ATVs and four-wheel drive vehicles) have been a main culprit in the spread of undesirable seed. When vehicles are driven through weed-infested areas, seed may become lodged in tire treads or in any of the multiple available crevices in the undercarriage, or may stick to vehicles with splattered mud. Seeds may be transported for hundreds of miles before they become dislodged (BLM 1996a). For this reason, vehicles that traverse any portion of the Project Area become a potential vector for further infestations of noxious weeds. Companies operating in areas identified with infestations of weeds would be required to submit an IPM before approval of their APDs. If Companies are operating in areas with known infestations of noxious weeds, they may be required to wash their vehicles upon leaving those areas. People who have collected seeds on their clothes or boots after walking through weeds should remove the seed before they travel to a new area.

Noxious weeds have the ability to displace native vegetation and hinder reclamation efforts. Minimizing establishment and spread of unwanted invasive species on or near disturbed areas is of critical importance after reclamation efforts have begun. Effective reclamation of disturbed sites is best achieved when natural vegetative succession develops unimpeded by invasion of undesirable plant species. When areas surrounding disturbed sites are infested with noxious weeds, desirable species, such as in an approved seed mix or pioneer species surrounding the site, are not able to compete, which disrupts the successional balance necessary for restoration of the native plant community.

Education of employees working in the region on the proper methods of avoiding seed dispersal is probably one of the most cost-effective methods of controlling the spread of noxious weeds. Many species of noxious weeds are being managed with biological control agents. Numerous state and federal laws regulate the distribution of noxious weed seed in any seed mix available to the public. As long as seed intended for reclamation is bought from a distributed certified by the State of Wyoming, the potential for introduction of noxious weeds through seed mixes is minimal. Other factors that can minimize the spread of noxious weeds include inspection of sources of rock and gravel before they are purchased and applied to roads, well-pads, or compressor stations. Application of herbicides should be considered when all other options have been exhausted or logically eliminated. County weed and pest control districts should be consulted for advice on effective methods of noxious weed control. If weed mitigation and preventative procedures were applied to all construction and reclamation practices, the impact of noxious weeds would be minimized.

Disturbances associated with construction of well pads, compressor stations, roads, reservoirs, and other facilities would provide opportunities for the invasion and establishment of noxious weeds. The extent of these invasions is difficult to predict and would be influenced by many factors, including the areal extent of disturbance, the extent of existing weed infestations that would provide a source of seed, movement of equipment from areas infested with weeds to areas that are not yet infested, the effectiveness of mitigation measures designed to prevent infestations of noxious weeds, and the time lag between the end of disturbance and the successful completion of reclamation.

Surface discharge of produced water from CBM wells has the potential to alter vegetation patterns in areas downstream of discharge points. The increased availability of water along normally dry stream channels could cause an increase in the extent of riparian and wetland vegetation and a corresponding decrease in upland vegetation that formerly occupied these areas. This shift in vegetation types would provide another type of disturbance that could be exploited by noxious weeds. The extent of these changes depends on the locations chosen for discharge points and on the existing vegetation downstream.

Another potential indirect effect on vegetation resources in the Project Area would be increases in levels of water and rates of flow through stream corridors. This effect is discussed in detail in the section on Wetlands/Riparian Areas. Vegetation communities at particular risk of alteration as a result of rising stream levels are shrublands along the upland border of riparian areas. Two species that display intolerance to inundation of root-zones are Wyoming big sagebrush and rabbitbrush. The vigor of big sagebrush is reduced in response to short periods of surface flooding and flooding for a period of 21 to 28 days can result in complete mortality of big sagebrush (Ganskopp 1986). The same study concluded that rabbitbrush experienced complete mortality after 28 to 35 days of inundation. Greasewood showed more tolerance to flooding, enduring 40 to 42 days of flooding before any visible effects were detected and 60 days of continual flooding before any wilting appeared. A die-off of shrubs along the edges of riparian areas would likely occur long before riparian species would be able to migrate laterally and take advantage of the open space with high availability of water. Instead, an area perfectly suited for invasion of noxious weeds would develop. Areas where species mortality occurs should be actively seeded with desirable species before noxious weeds invade.

Changes in the salinity of water pose another indirect effect to vegetation resources within the Project Area. Vegetation communities develop in association with certain environmental conditions, such as types of soil present and availability of water. Some of the water produced by CBM wells and discharged using the various water-handling methods would alter the concentration of salt in water available to plants. Damage to plants is likely when severe fluctuations in the availability of nutrients occur. For example, high concentrations of calcium ions in the soil solution often prevent plants from absorbing potassium efficiently (Bernstein 1964). Increases in salinity may favor the establishment of noxious weeds. Shafroth (1995) has shown saltcedar to be less susceptible than Fremont cottonwood to many of the negative effects of higher salinities. It is likely that higher salinity in soil along many stream and river channels has favored the establishment of saltcedar over cottonwood, a possible explanation for the increase of saltcedar along most of the major drainages within the Project Area.

Other than the alteration of vegetation along drainages, other changes in vegetation patterns may occur. Large, contiguous stands of vegetation could be fragmented by construction of well pads, roads, pipeline corridors, and other facilities. Disturbance followed by reclamation would alter the composition of species in reclaimed areas relative to undisturbed areas by replacing diverse native communities with communities consisting of a few favored reclamation species.

The application of water at LAD sites would increase ground cover and productivity and alter species composition, providing a potential opportunity for aggressive species, including noxious weeds, to establish. Application of water at LAD sites would reduce the presence of certain plant species that are not tolerant of irrigation, such as sagebrush, while favoring species that are capable of exploiting the increased amount of water that would be available. The introduction of salts in produced water at LAD sites could alter soil chemistry and affect both the composition of plant species and production of biomass. Excessive build-up of salt in soils could result in decreases in productivity and loss of native species that are sensitive to high concentrations of salt. Soil chemistry would be monitored during the life of the project and mitigation measures would be applied to reduce these impacts. Use of a rest-rotation system of water application and the use of soil amendments to reduce concentrations of salt are two possible mitigation measures. These measures would be developed on a site-specific basis, taking into account local properties of soil, species of plants present, the particular salts or other contaminants that are causing problems, and the objectives of the managing agency or surface owner.

The long-term effect of these shifts in vegetation patterns would be a reduction in biodiversity within and near disturbed areas. Where native vegetation provides an essential component of habitats for wildlife, such as the requirement of sage grouse for large, healthy stands of sagebrush, these shifts in vegetation patterns would result in decreased quality of habitats for wildlife. Some of these changes in vegetation could occur in areas that have been specifically identified as important to the conservation of biological diversity. The alteration and potential loss of biodiversity associated with project-related activities is difficult to quantify, but is not expected to have any obvious effect on biodiversity in the Project Area as a whole. Even if diversity of all species of plants in the entire disturbed area were to be reduced to some rudimentary level, only a small percentage of the landscape in each sub-watershed would be affected. The remaining undisturbed vegetation would retain a level of biodiversity essentially equivalent to pre-project conditions.

Alternatives 2A and 2B

Direct Effects

Under Alternative 2A and 2B, the numbers and locations of new CBM and conventional wells would be identical to Alternative 1. However, Alternatives 2A and 2B differ in the water handling facilities and their associated disturbances. Facilities to handle produced CBM water would disturb 36,263 acres under Alternative 2A and 32,653 acres under Alternative 2B. All disturbances associated with Alternative 2A and Alternative 2B would occur in the same vegetation types, land ownerships, and sub-watersheds as Alternative 1. Thus, the distributions of short-term disturbances to vegetation shown on Table 4–17 and Table 4–18 and the long-term disturbances shown on Table 4–19 and Table 4–20 also would apply to Alternatives 2A and 2B. Overall, Alternative 2A would disturb 211,643 acres of vegetation in the short term and 102,658 acres over the long term. In contrast, Alternative 2B would disturb 102,658 acres of vegetation in the short term and 99,048 acres over the long term.

As suggested above, the primary difference between Alternative 1 and Alternatives 2A and 2B, in terms of direct disturbance of vegetation, is the relative proportion of disturbance caused by the different types of facilities for handling produced CBM water. The total amounts of vegetation disturbed by facilities for handling produced water for Alternative 2A and 2B are more than that for Alternative 1 because both alternatives would involve construction of a larger number of impoundments, which would result in greater surface disturbance. Total disturbances for Alternatives 1, 2A, and 2B are greater than for Alternative 3 because that alternative involves many fewer new wells.

Indirect Effects

Indirect effects to vegetation as a result of Alternatives 2A and 2B would be similar to Alternative 1. Disturbances associated with construction of well pads, compressor stations, roads, reservoirs, and other facilities would provide opportunities for the invasion and establishment of noxious weeds. The increased availability of water at LAD sites would increase ground cover and alter the species composition by providing an opportunity for aggressive species, including noxious weeds, to establish.

Surface discharge of produced water from CBM wells has the potential to alter vegetation patterns in areas downstream of discharge points. This shift in vegetation types would provide another type of disturbance that could be exploited by noxious weed species. Disturbance followed by reclamation would alter the species composition of reclaimed areas. The long-term effect of these shifts in vegetation patterns would be a reduction in biodiversity within and adjacent to disturbed areas. The differences between the two water-handling scenarios in terms of indirect impacts are expected to be in proportion to the differences in direct impacts.

Alternative 3

Direct Effects

Implementation of Alternative 3 would disturb more than 82,600 acres of vegetation (79,052 acres for CBM facilities and 3,581 acres for non-CBM facilities), which is 1 percent of the Project Area. Almost 71,000 acres of vegetation would be disturbed in the short term to construct facilities to extract and transport CBM and non-CBM resources. Another 11,683 acres would be disturbed for the construction of facilities to handle produced water.

The disturbances projected under this alternative would involve 12 of the 14 vegetation types identified in the Project Area and would occur primarily on state and private property (Table 4-21 and Table 4-22). The aspen and herbaceous riparian vegetation types would not be disturbed. Direct disturbance of vegetation would occur in 17 of the 18 sub-watersheds within the Project (Table 4-22). The only sub-watershed that would not be affected would be the North Fork Powder River.

In contrast, more than 38,500 acres of vegetation, or 0.5 percent of the Project Area, would be affected over the long term for CBM and non-CBM facilities. As with the short-term disturbances, the long-term disturbances projected under this alternative would involve 12 of the 14 vegetation types identified in the Project Area and would occur primarily on state and private property (Table 4–23 and Table 4–24). Although at least some of 12 vegetation types would be disturbed, most of the long-term disturbance would involve the prairie grassland and sagebrush shrubland types. Disturbances associated with the facilities for handling produced CBM water also would encompass almost 11,700 acres over the long term.

Indirect Effects

Implementation of Alternative 3 would result in lower potential for the occurrence of indirect effects to vegetation types within the Project Area than Alternatives 1, 2A, or 2B because of the reduced number of wells, roads, ancillary facilities, pipelines, and water handling facilities. After the life of the project, most roads and facilities would be removed and the disturbed areas would be reclaimed and returned to pre-project uses.

Surface discharge of produced water from CBM wells has the potential to alter vegetation patterns in areas downstream of discharge points. This shift in vegetation types would provide another type of disturbance that could be exploited by noxious weed species. Disturbance followed by reclamation would alter the species composition of reclaimed areas. The long-term effect of these shifts in vegetation patterns would be a reduction in biodiversity within and adjacent to disturbed areas. This effect would be less for Alternative 3 than for Alternatives 1, 2A, and 2B.

Cumulative Effects

Implementation of each of the alternatives would contribute to cumulative effects to vegetation in the Project Area. Cumulative short- and long-term disturbance to vegetation by alternative for each surface owner is shown in Table 4–25. Cumulative short- and long-term disturbance to vegetation by alternative for each subwatershed is shown in Table 4–26. Included in Table 4–25 and Table 4–26 are the cumulative direct effects of oil and gas (both conventional and CBM) development, including projected effects of CBM development on private surface lands with private mineral ownership. The data for Alternative 3 do not include potential new federal wells that would be developed in response to drainage caused by production on adjacent state or fee minerals. Additional oil and gas development (both conventional and CBM) may occur later beyond the level considered in this analysis. Other activities that would contribute to cumulative effects on vegetation in the Project Area include mining for coal, uranium; sand, gravel, and scoria; ranching; agriculture; construction of new roads and railroads; and the development of new rural and urban housing.

Cumulative short- and long-term disturbance to vegetation by alternative for vegetation type is shown in Table 4–27. Included in Table 4–27 are the cumulative direct effects of oil and gas (both conventional and CBM) development, including projected effects of CBM development of private surface lands with private mineral ownership.

BLANK PAGE

Table 4–21 Short-term Vegetation Disturbance by Surface Owner — Alternative 3

Vegetation Type	Disturbance[1] (acres)					
	BLM					
	BFO	CFO	FS	State	Private	Total
Agriculture	0	0	0	66	871	937
Aspen	0	0	0	0	0	0
Barren	0	0	0	150	668	818
Coniferous Forest	0	0	6	65	113	184
Forest Riparian	0	0	0	0	6	6
Herbaceous Riparian	0	0	0	0	0	0
Mixed Grass Prairie	0	0	11	1,968	9,345	11,324
Other Shrubland	0	0	0	3	8	11
Sagebrush Shrubland	0	0	462	2,822	17,822	21,106
Shortgrass Prairie	0	0	692	4,886	27,241	32,819
Shrubby Riparian	0	0	0	50	215	265
Urban/Disturbed	0	0	0	0	3	3
Water	0	0	0	4	156	160
Wet Meadow	0	0	3	313	2,642	2,958
Total	0	0	1,174	10,327	59,090	70,591

Note:

1. Figures do not include the disturbances for water handling facilities (11,683 acres) or CMFs (356 acres), which were not site-specifically located in the GIS database.

Table 4-22 Short-term Vegetation Disturbance by Sub-watershed — Alternative 3

	Disturbance[1] (acres)														
Sub-watershed	Agriculture	Aspen	Barren	Coniferous Forest	Forest Riparian	Herbaceous Riparian	Mixed Grass Prairie	Other Shrublands	Sagebrush Shrublands	Shortgrass Prairie	Shrubby Riparian	Urban/ Disturbed	Water	Wet Meadow	Total
Little Bighorn River	0	0	0	0	0	0	11	0	3	0	0	0	0	0	14
Upper Tongue River	337	0	52	5	0	0	2,993	0	991	825	146	0	0	1,245	6,594
Middle Fork Powder River	0	0	0	0	3	0	3	3	3	11	0	0	0	0	23
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	16	0	275	14	0	0	1,455	0	4,132	7,174	11	0	0	125	13,202
South Fork Powder River	0	0	0	3	0	0	3	0	0	3	0	0	0	0	9
Salt Creek	0	0	0	0	0	0	0	0	104	461	0	0	0	0	565
Crazy Woman Creek	0	0	60	3	0	0	404	0	1,323	1,937	0	0	0	0	3,727
Clear Creek	477	0	70	18	0	0	2,289	3	1,492	2,254	90	0	152	1,246	8,091
Middle Powder River	3	0	7	16	0	0	144	0	185	163	3	0	0	29	550
Little Powder River	35	0	75	88	0	0	1,949	0	3,160	2,193	12	0	0	149	7,661
Little Missouri River	3	0	0	0	0	0	50	0	14	19	0	0	0	6	92
Antelope Creek	51	0	52	26	0	0	234	0	3,238	10,222	0	0	0	0	13,823
Dry Fork Cheyenne River	3	0	0	0	3	0	19	0	6	14	0	0	0	0	45
Upper Cheyenne River	0	0	0	3	0	0	20	0	431	980	0	0	0	0	1,434
Lightning Creek	0	0	0	0	0	0	30	5	22	11	0	0	0	0	68
Upper Belle Fourche River	12	0	227	8	0	0	1,692	0	5,985	6,552	3	0	8	158	14,645
Middle North Platte Casper	0	0	0	0	0	0	28	0	17	0	0	3	0	0	48
Total	937	0	818	184	6	0	11,324	11	21,106	32,819	265	3	160	2,958	70,591

Note:

1. Figures do not include the disturbances for water handling facilities (11,683 acres) or CMFs (356 acres), which were not site-specifically located in the GIS database.

Table 4-23 Long-term Vegetation Disturbance by Surface Owner — Alternative 3

Vegetation Type	Disturbance[1] (acres)					
	BLM					
	BFO	CFO	FS	State	Private	Total
Agriculture	0	0	0	25	319	344
Aspen	0	0	0	0	0	0
Barren	0	0	0	54	258	312
Coniferous Forest	0	0	4	37	61	102
Forest Riparian	0	0	0	0	5	5
Herbaceous Riparian	0	0	0	0	0	0
Mixed Grass Prairie	0	0	9	750	3,639	4,398
Other Shrubland	0	0	0	2	7	9
Sagebrush Shrubland	0	0	185	1,089	6,772	8,046
Shortgrass Prairie	0	0	251	1,811	10,160	12,222
Shrubby Riparian	0	0	0	20	80	100
Urban/Disturbed	0	0	0	0	2	2
Water	0	0	0	1	56	57
Wet Meadow	0	0	2	114	977	1,093
Total	0	0	451	3,903	22,336	26,690

Note:

1. Figures do not include the disturbances for water handling facilities (11,683 acres) or CMFs (143 acres), which were not site-specifically located in the GIS database.

139

Table 4-24 Long-term Vegetation Disturbance by Sub-watershed — Alternative 3

	Disturbance[1] (acres)														
Sub-watershed	Agriculture	Aspen	Barren	Coniferous Forest	Forest Riparian	Herbaceous Riparian	Mixed Grass Prairie	Other Shrublands	Sagebrush Shrublands	Shortgrass Prairie	Shrubby Riparian	Urban/ Disturbed	Water	Wet Meadow	Total
Little Bighorn River	0	0	0	0	0	0	9	0	2	0	0	0	0	0	11
Upper Tongue River	125	0	19	2	0	0	1,105	0	346	294	55	0	0	442	2,388
Middle Fork Powder River	0	0	0	0	3	0	2	2	2	9	0	0	0	0	18
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	9	0	102	6	0	0	519	0	1,504	2,644	4	0	0	47	4,835
South Fork Powder River	0	0	0	2	0	0	2	0	0	2	0	0	0	0	6
Salt Creek	0	0	0	0	0	0	0	0	41	164	0	0	0	0	205
Crazy Woman Creek	0	0	21	2	0	0	138	0	457	687	0	0	0	0	1,305
Clear Creek	170	0	25	8	0	0	828	2	524	773	32	0	54	448	2,864
Middle Powder River	2	0	4	7	0	0	66	0	78	69	2	0	0	20	248
Little Powder River	12	0	33	58	0	0	863	0	1,382	1,029	5	0	0	70	3,452
Little Missouri River	2	0	0	0	0	0	42	0	12	16	0	0	0	5	77
Antelope Creek	18	0	18	9	0	0	83	0	1,150	3,618	0	0	0	0	4,896
Dry Fork Cheyenne River	2	0	0	0	2	0	16	0	5	12	0	0	0	0	37
Upper Cheyenne River	0	0	0	1	0	0	7	0	163	390	0	0	0	0	561
Lightning Creek	0	0	0	0	0	0	26	5	19	9	0	0	0	0	59
Upper Belle Fourche River	4	0	90	7	0	0	668	0	2,347	2,506	2	0	3	61	5,688
Middle North Platte Casper	0	0	0	0	0	0	24	0	14	0	0	2	0	0	40
Total	344	0	312	102	5	0	4,398	9	8,046	12,222	100	2	57	1,093	26,690

Note:

1. Figures do not include the disturbances for water handling facilities (11,683 acres) or CMFs (143 acres), which were not site-specifically located in the GIS database.

BLANK PAGE

Table 4–25 **Cumulative Oil and Gas (including CBM) Direct Impacts to Vegetation by Alternative and Surface Owner**

	Proportion of Surface Owner Area Disturbed			
	Alternatives 1, 2A, and 2B		Alternative 3	
Surface Owner	Short term (Percent)	Long term (Percent)	Short term (Percent)	Long term (Percent)
Buffalo FO	2.50	1.03	0.14	0.14
Casper FO	0.13	0.12	0.09	0.09
FS	2.90	1.30	0.69	0.41
State	2.31	1.21	2.19	1.16
Private	2.30	1.44	1.56	0.96
Total	2.73	1.36	1.42	0.86

Table 4–26 **Cumulative Oil and Gas (including CBM) Direct Impacts to Vegetation by Alternative and Sub-watershed**

	Proportion of Sub-watershed Disturbed			
	Alternatives 1, 2A, and 2B		Alternative 3	
Sub-watershed	Short term (percent)	Long term (percent)	Short term (percent)	Long term (percent)
Little Bighorn	0.03	0.02	0.03	0.02
Upper Tongue River	1.12	0.48	1.00	0.43
Middle Fork Powder	0.03	0.03	0.02	0.02
North Fork Powder	0.01	0.01	0.00	0.00
Upper Powder River	3.89	1.67	1.23	0.70
South Fork Powder	0.06	0.06	0.06	0.06
Salt Creek	0.84	0.36	0.44	0.21
Crazy Woman Creek	2.11	0.76	0.72	0.28
Clear Creek	2.24	0.84	1.56	0.60
Middle Powder	3.08	2.24	1.89	1.76
Little Powder	2.97	1.97	1.93	1.45
Little Missouri	0.76	0.66	0.33	0.29
Antelope	6.28	2.52	2.53	1.18
Dry Fork Cheyenne	0.13	0.12	0.10	0.10
Upper Cheyenne	2.30	1.35	1.45	1.03
Lightning Creek	0.33	0.33	0.31	0.31
Upper Belle Fourche	4.67	2.90	3.51	2.45
Middle North Platte Casper	0.08	0.08	0.06	0.05
Total	2.73	1.36	1.42	0.86

|41|

Table 4–27 Cumulative Oil and Gas (including CBM) Direct Impacts to Vegetation by Alternative and Vegetation Type

	Proportion of Vegetation Type Disturbed			
	Alternatives 1, 2A, and 2B		Alternative 3	
Vegetation Type	Short term (percent)	Long term (percent)	Short term (percent)	Long term (percent)
Agriculture	1.00	0.45	0.95	0.43
Aspen	0.00	0.00	0.00	0.00
Barren	2.33	1.33	1.40	0.96
Coniferous Forest	0.41	0.25	0.14	0.10
Forest Riparian	0.09	0.08	0.09	0.08
Herbaceous Riparian	0.16	0.15	0.13	0.13
Mixed Grass Prairie	1.68	0.93	1.17	0.73
Other Shrubland	0.06	0.05	0.05	0.04
Sagebrush Shrubland	3.10	1.62	1.64	1.06
Shortgrass Prairie	3.42	1.60	1.54	0.91
Shrubby Riparian	0.53	0.25	0.51	0.23
Urban/Disturbed	0.07	0.05	0.07	0.05
Water	1.95	0.79	1.90	0.78
Wet Meadow	2.36	1.10	2.20	1.03
Total	2.73	1.36	1.42	0.86

Within the Project Area, coal mining continues to disturb more vegetation every year. Surface disturbance on permitted coal mines in the PRB increased 6,795 acres from 90,751 acres in 2000 to 97,546 acres in 2001. Total acres of reclaimed land during the same period rose from 16,667 acres to 18,104 acres, an increase of 1,437 acres (Christensen 2002). For each additional 1,000 acres disturbed by coal mining in the Project Area during year 2001, approximately 211 acres were reclaimed. WDEQ defines reclaimed land as affected land that has been backfilled, graded, the topsoil has been replaced, and permanently seeded according to approved practices specified in the reclamation plan (Christensen 2002). The acres of reclaimed land mentioned above do not represent land that has been returned to its natural, pre-mining vegetative community. Although reclamation plans for approved mining permits are implemented with the intention of re-establishing pre-mining conditions, actual establishment of native, self-sustaining vegetation communities may take decades to achieve.

The 4,400 acres currently disturbed by uranium mining are not expected to increase substantially in the near future. Sand, gravel, and scoria mining, which have disturbed 1,200 acres, also are not expected to expand substantially. Agriculture has affected 113,643 acres of lands that were formally occupied by native vegetation. Agricultural areas are not expected to substantially expand or contract in the near future. Urban development has resulted in the loss of 4,362 acres of native vegetation. A minor amount of new rural and urban development is expected in the near future, but the amounts or types of vegetation disturbance have not been estimated. Cumulative impacts to vegetation from roads, railroads, and rural development have not been estimated, except where road impacts are part of existing or proposed oil and gas development. These road impacts are included in Table 4-25 and Table 4-26.

All non-oil and gas impacts are estimated to have resulted in the loss of 2.8 percent of the native vegetation in the Project Area. When non-oil and gas impacts are combined with the existing and projected impacts from oil and gas development, 5.5 percent of the vegetation in the Project Area would be disturbed in the short term and 4.2 percent of the vegetation in the Project Area would be disturbed over the long term, depending on the alternative selected.

The total acreage affected by development of CBM would not be disturbed simultaneously because development would occur over the life of the project. Some of the disturbed acreage would be reclaimed or would be in the process of being reclaimed when new disturbances are initiated. Development of CBM is, however, expected to occur at a rate faster than abandonment and reclamation of wells. In the near future (5 to 10 years), the amount of vegetation disturbed is likely to increase, although the anticipated life of CBM wells (10 years) suggests that reclamation would eventually overtake development of new wells, resulting in a net decrease in disturbed vegetation over the long term.

As of 1995, an estimated 8.5 million acres of BLM property in the western United States had been infested by serious weed populations and infestations were spreading at an accelerating rate, which BLM estimates at 2,300 acres per day (BLM 1995a). If combined with estimates of infestation on private property, these estimates would easily double. Some species of noxious weeds are spreading quickly within the Project Area. Over the last 3 years (1999 through 2002), the area of infestation for Canada thistle has almost doubled in Campbell County. Estimates for Scotch thistle and salt-cedar suggest they have tripled their distribution in Johnson County over the same period, with leafy spurge, Russian knapweed, and hoary cress more than doubling. Russian knapweed has more than doubled over the same period in Converse County. According to the Campbell County Weed and Pest Control District, spotted knapweed has the potential of become a serious problem as a result of the scattered invasions throughout the county, especially along roads (Griswold 2002). All species of noxious weeds identified in Chapter 3 have the potential to damage the health of the ecosystem if proper management techniques are not implemented.

Salinity in soil has increased along many stream and river channels in the western United States through the reduced frequency of salt-leaching flooding that resulted from construction of many reservoirs One potentially beneficial effect of development of CBM is the possibility that increased stream flows will scour salts from riparian zones where the lack of flooding in recent years has allowed salt to accumulate.

In areas reclaimed after development of CBM, the reclaimed areas often differ substantially from undisturbed areas in terms of vegetation cover. Reclaimed areas may not serve ecosystem functions now provided by undisturbed vegetation communities, particularly in the short term, when species composition, shrub cover, and other environmental factors would likely be different. Establishment of noxious weeds and alteration of vegetation along drainages and reclaimed areas has the potential to alter the distribution of the types of vegetation. As a result, alteration of biodiversity may occur through the overall effects of the project on vegetation.

Wetlands/Riparian Areas

A number of potential effects to wetlands and riparian areas are associated with the extraction of CBM in the Project Area. This section summarizes the primary categories of effects to wetlands and riparian areas, which include (1) habitat loss and degradation from roads, well pads, and ancillary facilities; (2) road impacts other than direct loss of habitat; (3) impacts from the quantity of produced water; and (4) impacts from the quality of produced water.

Alternative 1

Habitat Loss/Degradation

Loss of wetlands and riparian areas would occur despite the intention to avoid these environmentally sensitive areas whenever possible. The largest proportion, about 80 percent, of the habitat disturbance would be caused by construction of linear facilities such as pipelines, roads, and power lines. Straight-line construction of these facilities is the most cost-effective method, so it can be assumed that wetlands and riparian areas would lie in the path of construction. Riparian areas, in particular, are likely to be crossed by roads, power line, and pipeline corridors. Well pads, compressor station pads, and many water handling facilities would not cause loss of wetlands and riparian areas because they would be located in upland sites. Some of the disturbance would be short term, such as construction of buried pipelines and overhead power lines, while other disturbances would be long term or essentially permanent, such as construction of roads. Habitat loss in wetlands and riparian areas would occur directly through construction of roads, pipelines, power lines, and some water handling facilities.

Habitat loss of wetlands and riparian areas can substantially affect plant and animal species that depend on these ecosystems. Many plants grow only in seasonally flooded or saturated soils associated with wetlands and riparian areas (1982). Additionally, amphibians, turtles, aquatic invertebrates, fish, waterfowl, shorebirds, small mammals, carnivores, and big game spend much of their life cycle in wetlands or are drawn to the habitats provided by wetlands and riparian areas for food, water, or shelter. Multiple small local populations of wetland species often exist through the ability to move between nearby wetlands and riparian areas. Local populations of wetland species are most vulnerable to extirpation because of the patchy, mosaic distribution of wetlands and riparian areas that are surrounded by large expanses of very different upland habitat (Gibbs 2000). A decrease in this habitat eliminates populations of local species and causes a reduction in the ecosystem values for the affected sub-watershed by diminishing the species richness of the ecological communities. Wetland habitat losses in various sub-watersheds of the Project Area may isolate certain less mobile species, such as amphibians, turtles, and insects. The habitat loss of wetlands and riparian areas can have large impacts on the ecological landscape of a specific watershed because of the disproportionately high species richness of wetlands and riparian areas (Brinson et al. 1981, University of Wyoming 2002).

Degradation of wetlands and riparian areas would occur because of indirect effects. Roads, well pads, or power lines that are adjacent to the habitat of wetlands and riparian areas may cause various wetlands species to disappear either from behavioral alterations or physical impacts. Decreases in the species richness of a particular wetland or wetland mosaic may not be detectable for several years for birds, reptiles, or amphibians, or even several decades for wetlands plants (Findlay and Bourdages 2000). The potential causes of these declines are many, including noise from road traffic, human activity, mechanized equipment, soil erosion, changes to hydrological patterns, and invasions by exotic species.

Nearly all (88 percent) wetlands and riparian areas in the Project Area occur on private lands (Table 3-24). About 1.5 percent of the privately owned wetlands and riparian areas would be disturbed in the short term, with other land ownerships being disturbed to a much lesser extent (Table 4–17). About 0.5 percent of the privately owned wetlands and riparian areas would be disturbed in the long term, with other land ownerships being disturbed to a much lesser extent (Table 4–19). Approximately 1.5 percent (3,500 acres) of the wetlands and riparian areas in the Project Area, mostly wet meadows (92 percent) in the Upper Tongue River and Clear Creek sub-watersheds, would be directly disturbed in the short term. Direct disturbance of vegetation in the wetlands and riparian areas of the Project Area would occur in 10 of the 18 sub-watersheds. Direct short-term disturbance would occur to 3 percent of the wetlands and riparian areas of the Clear Creek sub-watershed, 1 percent of the wetlands and riparian areas of the Upper Tongue River sub-watershed, and lesser amounts to the other affected sub-watersheds (Table 4–18). Disturbance would continue in the same sub-watersheds over the long term, but at lesser percentages and in smaller areal extent than the short-term disturbances to wetlands and riparian areas. The wetlands and riparian areas estimated to be disturbed over the long term in the Project Area total 0.5 percent (1,320 acres), almost entirely in wet meadows of the Upper Tongue River and Clear Creek sub-watersheds. Direct long-term disturbance would occur to 1 percent of the wetlands and riparian areas of the Clear Creek sub-watershed, 0.5 percent of the wetlands and riparian areas of the Upper Tongue River sub-watershed, and lesser amounts to the other affected sub-watersheds (Table 4–20).

Effects from Roads

Roads and their associated impacts, both immediate and delayed, are probably the major category of impact to wetlands and riparian areas in the Project Area. The ecological effects of roads have been extensively studied and reported in the scientific literature. Effects from roads have been documented on lands adjacent to wetlands at distances up to 2 kilometers (Findlay and Bourdages 2000). Some general effects from roads that apply to wetlands and riparian areas include alteration of the physical environment and facilitated spread of exotic species (Trombulak and Frissell 2000).

Mortality of wildlife from road construction would be an important impact if roads were sited through, or very near to, wetlands and riparian areas. These habitats serve as oases in arid environments, such as the Project Area, and draw large numbers of animal species from adjacent uplands. Species richness, as mentioned in Chapter 3, is particularly high for the wetlands and riparian areas of the sub-watersheds of the Project Area relative to the upland areas.

Roads alter the physical environment in many ways, including increased soil density, increased temperature, increased dust, changes in surface water flow, changes to surface runoff patterns, and sedimentation (Trombulak and Frissell 2000). These types of alterations caused by roads lead to greater sedimentation and increased surface water flows to wetlands and riparian areas that can change species compositions and adversely affect macroinvertebrate populations. Roads that are built within floodplains can redirect water, sediment, and nutrients between streams, wetlands, and riparian ecosystems to the detriment of water quality and ecosystem health (Trombulak and Frissell 2000). Overall, the presence of roads is highly correlated with changes in species composition, population sizes, and hydrologic and geomorphic processes that shape aquatic and riparian systems (Trombulak and Frissell 2000).

Effects from Produced Water Quantity

Water that is produced during extraction of CBM would be handled differently among the alternatives, but surface discharges that reach wetlands and riparian areas would affect them. All alternatives involve the continuous (year-round) surface discharge of produced water for the duration of the project. Not all of the produced water would reach wetlands and riparian areas associated with the main stems of the various sub-watersheds because of evaporation and percolation into the soil surface. Discharge rates for all alternatives average 6.58 gpm, or almost 11 acre-feet per year per well. The amount of water produced under Alternative 1, for example, that would reach the main stems of the various sub-watersheds ranges from 0.2 cubic feet per second (145 acre-feet per year) in the Salt Creek sub-watershed to 135 cubic feet per second (98,000 acre-feet per year) in the Upper Powder River sub-watershed (Table 4-4). Some of the discharges of produced water associated with Alternative 1 make a very large contribution to, or exceed, the natural mean monthly surface water flows of certain sub-watersheds, as shown in Table 4-13 and discussed in the section on Surface Water.

Increases in surface water flows would adversely affect existing wetlands and riparian areas because of the very large increase in volume. Major effects to be expected from produced water discharges may include the following: (1) increased erosion of channels and floodplains; (2) loss of riparian streambank vegetation; (3) changes to the composition and physical structure of the vegetation community in wetlands and riparian areas; and (4) raising of shallow groundwater table in floodplains. Erosion of channels and floodplains would increase turbidity in the water column, thus adversely affecting plankton and macroinvertebrate production and growth rates (Mitsch and Gosselink 1993) that are the basis of aquatic food chains in the prairie streams of the Project Area. Increased erosion in riparian corridors leads to the increased deposition of sediments in downstream wetlands that raises biochemical oxygen demand and adversely affects wetland functioning at several trophic levels in the food web (Mitsch and Gosselink 1993).

Riparian streambank vegetation, including gallery forests of mature cottonwood trees, may be lost by bank undercutting caused by the increased surface water flows in channels. The loss of cottonwood trees and other streambank vegetation would decrease the amount of cover and food resources for wildlife within riparian corridors and increase stream water temperatures due to a reduction in shading of the stream by vegetation.

Community composition would change because of altered nutrient inputs caused by continuous, rather than seasonal water flows. Most wetland plant seeds require moist, but not flooded, conditions for germination and early seedling growth. Freshwater marshes with cyclic water levels, rather than continuous flows, produce the greatest number of plant seeds (Siegley et al. 1988). Continuous inputs of produced water would decrease the recruitment rate of new plants and alter the age structure and species composition of wetlands and riparian areas. Studies show that measures of biomass and net primary productivity are higher in wetland and riparian ecosystems that have pulsing, rather than flowing, hydroperiods. Stagnant or continuous hydroperiods, such as would be associated with the discharged produced water from the proposed project, cause measures that are lower still (Mitsch and Gosselink 1993). The temporal cycles and spatial patterns of invertebrate species and concentrations reflect the natural seasonal cycle of insect growth and emergence. These cycles are related to the cycles of vegetation growth and species abundance that depend on the normal seasonal and periodic fluctuations of the hydrology, such as summer drying and occasional droughts and floods (Voights 1976, Mitsch and Gosselink 1993).

Continuous high stream flows into wetlands and riparian areas would change the composition of species and dynamics of the food web. The shallow groundwater table would rise closer to the surface with increased and continuous stream flows augmented by produced water discharges. Vegetation in riparian areas, such as cottonwood trees, that cannot tolerate year-round inundated root zones would die and would not be replaced. Other plant species in riparian areas and wetland edges that favor inundated root zones would flourish, thus changing the plant community composition and the associated animal species. A rise in the shallow groundwater table would also influence the hydrology of wetlands by reducing or eliminating the seasonal drying periods that affect recruitment of plant species and species composition of benthic and water column invertebrates. These changes to the aquatic food web base would affect the higher trophic levels of fish and waterfowl abundance and species richness for wetlands and riparian areas.

Water handling facilities, such as on-stream impoundments, would cause similar changes to wetlands and riparian areas through alterations in volume, velocity, and timing of the stream flow. The magnitude of effects to specific subwatersheds would depend on the [illegible] number of facilities. On-stream impoundments would affect wetlands and riparian areas more than would impoundments located outside of the floodplain. The number and exact locations of the impoundments are not yet known, but would be established with APDs. On-stream impoundments would also cause an elevational increase in the shallow groundwater table of the associated floodplain through infiltration of the stored water and effects already described.

Produced water from CBM wells would be gathered for discharge at outfalls. Outfalls may feed into small stock reservoirs, constructed infiltration basins, or other facilities before the outflows reach surface drainages. No direct effects on wetlands and riparian areas would occur due to the containment reservoirs because they would be constructed in upland sites. Infiltration reservoirs would be constructed within floodplains or at upland sites. Infiltration reservoirs that are constructed within floodplains would affect the wetlands and riparian areas of the respective sub-watersheds, as previously described. The full extent of these direct disturbances cannot currently be quantified because the locations of the reservoirs have not been established.

No direct effects to wetlands and riparian areas would occur as a result of the creation of land application disposal sites or injection facilities. These sites would be located in upland areas away from drainages and floodplains. Water would be applied at agronomic rates at LAD sites so that there would be no runoff or infiltration of applied water that could reach surface drainages.

Discharges of produced water would decrease after the peak values (Table 4-13) are reached and would be terminated at the end of the project. Previously existing wetlands and floodplains that had expanded because of the increase in stream flows would experience vegetation dieback as the hydrology returned to normal conditions. Wildlife populations that depend on wetlands and riparian areas for food, cover, and water may decrease in abundance and wildlife species richness may be diminished. Salt scalds are accumulations of mineral salts in surface soil caused by evaporation that may appear within riparian corridors and along wetland edges. Salt scalds inhibit growth and recruitment of many wetland and upland plant species (DLWC 2000, Seelig 2000) and could perpetuate adverse saline conditions to wetlands via surface runoff of precipitation. New depressional wetlands or groundwater wetlands created by the increased stream flows during the life of the project would dry up after discharges of produced water cease and the hydrologic conditions return to normal. Associated wetland species communities could be eliminated in these locations and are not likely to be assimilated into the communities of remaining wetlands and riparian areas. Salt scalds could appear as the saline water and saline groundwater evaporates in the newly formed wetlands.

Impacts from Produced Water Quality

The water produced during extraction of CBM has been measured at 47 locations throughout the PRB for its mineral composition and other water quality parameters by the USGS (Rice et al. 2000). Details on water quality specific to the Project Area are included in the section on Surface Water Quality of Chapter 3. The USGS study reported that most concentrations of trace elements were at or below the analytical detection limits and no noticeable trends were apparent. This study and others cited in Chapter 3 indicate that the primary water quality parameters of interest regarding ecological impacts to wetlands and riparian areas from releases of produced water are salinity caused by high concentrations of sodium cations and sodicity caused by high concentrations of bicarbonate ions.

Average values are predicted for the proposed discharges of produced water to each of the sub-watersheds that would be affected by the project (Table 4-13)

M5

and are discussed in the section on Surface Water Quality. Substantial increases in the normal levels of salinity and sodicity in the surface waters of several of the Project Area's sub-watersheds by discharges of produced water would affect the ecosystem structure and functions of wetlands and riparian areas. The salinity and sodicity measures of the produced water discharges would not be ameliorated in the sub-watersheds where minimum mean flows are less than, and mean monthly flows are similar to, the rate of discharge for produced water that would reach the streams and rivers. Plant communities have been identified as the wetland biota most sensitive to increases in concentrations of salinity in water (Hart et al. 1991). The growth, vigor, and reproductive success of plant and animal species of aquatic and semi-aquatic systems, such as wetlands and riparian areas, depend on a range of tolerance to water quality parameters, including salinity, sodicity, pH, and others (Mitsch and Gosselink 1993). Additionally, increased salinity and longer periods of soil saturation or inundation can act synergistically to the detriment of many species of riparian plants (Hart et al. 1991). Above-normal concentrations of salinity cause stress to plants that can lead to dieback and changes in species community composition. The predicted range in the concentration of salinity of the produced water discharge for the project is greater than the threshold values for effects to plants (Hoepstad 2001, James and Hart 1993, Nielsen and Brock 2001), indicating that adverse effects would affect vegetation in wetlands and riparian areas in the seven sub-watersheds with predicted average concentrations of salinity in the middle or high end of the range of values (Table 4–13). However, injury to vegetation communities of wetlands and riparian areas may be avoided if the narrative water quality standards developed for the protection of agriculture are coincidentally protective of native wetlands vegetation species.

Biota of wetlands and riparian areas other than plants would also be adversely affected by increases in salinity. Benthic and water column invertebrates of wetlands are also sensitive to increases in salinity, with adverse effects appearing in some taxa at 1,000 mg/L TDS. The most sensitive of the invertebrate taxa are benthic multicellular organisms and certain insects, such as stoneflies, mayflies, caddisflies, and dragonflies (Hart et al. 1991). Waterfowl and fish depend directly these invertebrate taxa for food.

Increased sodicity in the floodplains of the main stems of the Project Area sub-watersheds would affect wetlands and riparian areas through amplified sedimentation within riparian corridors, including floodplain terraces. SARs of 13 or more may cause potentially irreversible changes to soil structure that reduce percolation of rainfall and surface water flows, restrict root growth, limit permeability of gases and moisture, and make tillage difficult (Seelig 2000, U.S. Salinity Laboratory Staff 1954). At least some of the average SARs for the affected sub-watersheds may be greater than 13, with the highest values potentially occurring in the Clear Creek and the Upper Tongue River sub-watersheds (Tables 4–7 and 4–10). The effects of increased sedimentation have been previously discussed in this section in terms of the increase in the velocity and volume of surface water flow in stream channels. Reduced percolation and the formation of an impermeable soil surface in areas of high clay content over large expanses of floodplains would increase the contribution of surface runoff to in-channel stream flows that are already high. The establishment and maintenance of riparian grasses, shrubs, and trees within the riparian corridor and in wetlands would be limited by the degraded soil structure caused by the highly sodic discharges of produced water. Additional information on the effects of an increased sodium absorption ratio on soils, agricultural crops, and native upland vegetation can be found in the sections on Soils, Land Use, and Vegetation.

Alternatives 2A and 2B

The numbers of well pads and the miles of linear facilities, such as roads, pipelines, and power lines, that may affect wetlands and riparian areas are the same for Alternatives 1, 2A, and 2B. The effects to wetlands and riparian areas from these facilities would therefore be the same for these alternatives. Alternatives 2A and 2B would result in similar percentages and areal extent of short- and long-term direct disturbances to wetlands and riparian areas as Alternative 1, but would result in greater direct disturbances than Alternative 3. The lack of differences in direct disturbance to wetlands and riparian areas is a result of the planned avoidance of these environmentally sensitive areas. Additional details about direct disturbances are included in Chapter 2.

Most of the affected sub-watersheds, with the exception of the Upper Belle Fourche River sub-watershed, would receive more discharges of produced water to streams and rivers under Alternatives 1 and 3 than under Alternatives 2A and 2B (Table 4-3). Therefore, the effects to wetlands and riparian areas from predicted quantity and quality of produced water would be less for Alternatives 2A and 2B than for Alternatives 1 and 3.

Alternative 3

A smaller number of facilities related to the extraction of CBM in the Project Area would be constructed under Alternative 3 than for the other alternatives and, thus, the extent of effects to wetlands and riparian areas would be proportionally less. The predicted rates of discharge for produced water that would reach the main stems of the various affected sub-watersheds would be the same as for Alternative 1 (Table 2-8). The effects to wetlands and riparian areas from quantity and quality of produced water previously discussed would be the same for this alternative. Most of the affected sub-watersheds, with the exception of the Upper Belle Fourche River sub-watershed, would receive more discharges of produced water to streams and rivers under Alternatives 1 and 3 than under Alternatives 2A and 2B (Table 4-3). Therefore, the effects to wetlands and riparian areas from predicted quantity and quality of produced water previously discussed would be greater for Alternatives 1 and 3 than for Alternatives 2A and 2B.

Cumulative Effects

Implementation of the alternatives would contribute to other types of effects on wetlands and riparian areas in the Project Area. Oil and gas extraction, in general, attempts to avoid environmentally sensitive areas such as wetlands and riparian areas. However, these types of projects are on the increase in the PRB. Future projects of a similar nature would have similar levels of effects to wetlands and riparian areas within the sub-watersheds. Other types of natural resource extraction projects might have more or fewer effects to wetlands and riparian areas of the region, although effects would likely be similar. Although resource extraction and infrastructure construction projects generally attempt to avoid wetlands and riparian areas, some types of projects, especially when they are linear, cannot avoid all impacts to these sensitive resources.

Much of the discussion of cumulative effects to vegetation is also relevant to wetlands and riparian areas. Coal, uranium, sand, gravel, and scoria mining; ranching; agriculture; road and railroad construction; and rural and urban development are likely to have some effect on wetlands and riparian areas via habitat loss or degradation, road development, and water quality degradation. These types of resource extraction and construction would increase in number and frequency within the PRB commensurate with an increase in the regional population. More details about cumulative effects to wetland/riparian vegetation are included in the total effects to vegetation, as shown on Table 4-27 and other sections within Chapter 4.

Noxious weeds, non-native plants, and exotic invertebrates are likely to invade wetlands and riparian areas via new roads throughout the Project Area. Invasions by alien species associated with new roads occurs via the creation of desired habitat by altering existing conditions, reducing competition with native species by stressing or removing them, and allowing easier movement across the landscape (Trombulak and Frissell 2000). Once noxious weeds and other alien species are introduced, it has historically been difficult to remove them from the landscape. The effects of noxious weeds and non-native plant species are discussed further in the section on Vegetation.

Wildlife

Terrestrial Species

The principal effects to terrestrial wildlife may include: (1) increased direct mortality (including legal hunting, poaching, collision with power lines and vehicles, electrocution on power lines, and nest loss); (2) the introduction of new habitats suitable for avaian and mammalian predators and thus a potential change in predation rates on other wildlife species; (3) direct loss or degradation of habitats; (4) indirect disturbance resulting from human activity (including harassment, displacement, diversion from public to private lands, noise and dust, altered nutritional status and reproductive success, and changes in habitat effectiveness); (5) habitat fragmentation (particularly through construction of roads); and (6) changes in population levels. The magnitude of effects to wildlife would depend on a number of factors including the natural history characteristics of each species and the recommended and required mitigation measures. The overall effects of the proposed project on wildlife would be similar among alternatives; however, the magnitude of these effects would vary along with the different levels of activity proposed for each alternative.

Direct disturbance of wildlife habitats would occur in each sub-watershed and under each alternative during the construction phase of the project. In an effort to return habitats to wildlife use, unused portions of well sites would be reclaimed during the production phase. After the end of the production phase, well fields and ancillary facilities would be removed and disturbed areas would be reclaimed. Seed mixes approved by the appropriate agency, many of which are intended to be beneficial to wildlife species, would be used to revegetate abandoned well pads and areas occupied by ancillary facilities. The amount of time these lands are unsuitable as wildlife habitats is variable and may depend on one or more of the following: productive life span of the well, success of mitigation, reclamation techniques, and local weather conditions. Reclamation of habitats dominated by grasses and forbs is expected to be successful within several years; however, habitats dominated by shrubs and trees may take 8 to 20 years or more to successfully re-establish. Consequently, the disturbance of forest and shrub habitats would represent a long-term loss beyond the end of the production phase to species that depend on this vegetation for forage or shelter. In addition, an unknown percentage of roads would not be reclaimed, resulting in permanent loss of wildlife habitats.

Indirect effects would occur in varying degrees during the construction, production, and decommissioning and abandonment phases of the project and would continue after abandonment in areas where roads are not reclaimed. These effects would be the greatest during construction, when the highest level of activity would occur, and would decrease during production. Wildlife may avoid areas of these activities and use other locations in response to the increased levels of human activity, equipment operation, vehicular traffic, and noise associated with all phases of the project. This avoidance could result in the under-use of otherwise suitable habitats; therefore, the effectiveness of these habitats would be diminished. The displacement of wildlife from disturbed areas could lead to the over-use of suitable habitats in undisturbed areas, increasing competition for limited resources in these areas. Wildlife distribution patterns could be altered. The degree of habitat avoidance would vary between species and among individuals of any specific species. The pattern of development is not known; however, it is anticipated that development would occur throughout the Project Area, based primarily on the objectives of each leaseholder. Development may or may not occur in an orderly or staged fashion. For this reason, no attempt has been made to predict patterns of displacement or under- or over-use of resources by displaced wildlife.

The effects of habitat fragmentation would vary by wildlife species. For some species, fragmentation could result in substantial disruptions of movement, reduce connectivity between populations, and may result in the extirpation of local populations. For other species, the type and extent of fragmentation anticipated with this project could have no noticeable effect. The net result of the types of impacts discussed above and the interactions among these types of impacts would vary among species, but for some of the more sensitive species may result in population declines.

Mitigation measures designed to minimize effects to wildlife species are provided at the end of Chapter 4. These measures were developed to address the more substantial effects that could occur from the proposed project and their effects on the species of wildlife that are of higher interest or that are more likely to be affected. Each of the alternatives includes more than 12,000 wells that would be located on private lands with private minerals. Mitigation measures contained

(S)

in this document would be recommended, but BLM could not require their implementation, for these wells. This lack of required mitigation measures on private lands was taken into account in the impact assessment for each species or group of species discussed below.

Wildlife Habitats

The direct, indirect, and cumulative impacts to the vegetation types that provide habitats for wildlife are discussed in the section on Vegetation in Chapter 4. One of the impacts of the proposed project on habitats would be an increase in density of roads. Table 4–28 shows the proposed increase in density of roads under each alternative and the cumulative (existing and proposed) road density for each sub-watershed. The specific effects of this change in density of roads are discussed, where applicable, for each species or group of species below.

Big Game

Direct and indirect effects to big game and their ranges would occur as a result of activities proposed under each alternative. Direct effects to habitats that would result from construction of CBM wells, compressors, non-CBM wells, and other facilities were estimated by applying facility-specific disturbance factors (Chapter 2) to the proposed number of each type of facility. These facility-specific disturbances were then summed and used to estimate the number of acres that would be directly disturbed for each range type by surface owner and sub-watershed. Disturbance acres from water handling facilities were estimated for direct disturbance to big game by sub-watershed. Other direct effects are discussed qualitatively.

Table 4–28 Proposed and Cumulative Road Density by Sub-Watershed

Sub-watershed	Road Density (miles per square mile)			
	Alternative		Cumulative with Alternative	
	1, 2A, or 2B	3	1, 2A, or 2B	3
Little Bighorn River	0.00	0.00	1.47	1.47
Upper Tongue River	0.64	0.57	2.52	2.45
Middle Fork Powder River	0.00	0.00	1.54	1.54
North Fork Powder River	0.00	0.00	1.70	1.70
Upper Powder River	2.06	0.51	3.82	2.27
South Fork Powder River	0.00	0.00	1.45	1.45
Salt Creek	0.48	0.26	2.24	2.02
Crazy Woman Creek	1.34	0.45	2.79	1.90
Clear Creek	1.43	0.98	3.11	2.66
Middle Powder River	0.84	0.14	2.79	2.08
Little Powder River	1.01	0.52	3.42	2.93
Little Missouri River	0.00	0.00	1.64	1.64
Antelope Creek	4.46	1.62	6.81	3.96
Dry Fork Cheyenne River	0.00	0.00	1.78	1.78
Upper Cheyenne River	0.92	0.43	3.16	2.78
Lightning Creek	0.00	0.00	1.99	1.99
Upper Belle Fourche River	1.79	1.11	5.15	4.47
Middle North Platte River	0.00	0.00	1.63	1.63
Total	1.40	0.59	3.44	2.63

163

Indirect effects to big game are generally treated qualitatively, except for the discussion of habitat effectiveness and road density. It has been well documented (for example, by Rost and Bailey 1979, Ward 1976) that big game species reduce their use of habitats that are near human disturbance. Areas of habitat that are avoided because of human activities or the consequences of human activities are less effective at supporting populations of big game. An estimate of the reduction in habitat effectiveness by sub-watershed is shown in Table 4–29 for each big game species that would be affected by the proposed project. The area subject to this impact is not lost to each species, but their use of this area is reduced by some unknown amount that depends on many factors such as the spatial and temporal scale of the disturbance, natural history characteristics of each species, and the habituation of individual animals to each type of disturbance. An accurate assessment of the potential reduction in habitat effectiveness is not possible without knowledge of the spatial location of proposed facilities, especially roads (Lyon 1983). Because the spatial location of the proposed facilities is not known, another measure of indirect impacts, road density, was also estimated, as discussed above. Road density is related to habitat effectiveness and provides a good measure for estimating indirect effects to big game (Rowland et al. 2000).

Table 4–29 Estimated Reduction in Big Game Habitat Effectiveness

	Habitat Effectiveness Reduction (percent)							
	Pronghorn		White-tailed Deer		Mule Deer		Elk	
	Alternative		Alternative		Alternative		Alternative	
Sub-watershed	1, 2A, 2B	3	1, 2A, 2B	3	1, 2A, 2B	3	1, 2A, 2B	3
Little Bighorn River	0	0	0	0	0	0	0	0
Upper Tongue River	12	10	6	5	16	14	3	3
Middle Fork Powder River	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0
Upper Powder River	47	11	2	1	53	12	9	4
South Fork Powder River	0	0	0	0	0	0	0	0
Salt Creek	12	6	0	0	12	6	6	3
Crazy Woman Creek	31	10	4	1	34	11	11	5
Clear Creek	32	22	9	6	36	25	[illegible]	5
Middle Powder River	16	3	2	0	21	3	0	0
Little Powder River	22	11	3	2	23	12	0	0
Little Missouri River	0	0	0	0	0	0	0	0
Antelope Creek	100	40	3	1	99	36	13	13
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0
Upper Cheyenne River	20	9	0	0	16	8	37	17
Lightning Creek	0	0	0	0	0	0	0	0
Upper Belle Fourche River	43	26	1	0	24	14	1	[illegible]
Middle North Platte River	0	0	0	0	0	0	0	0
Total	30	13	3	1	32	13	6	4

Several assumptions were made for each measure that was developed. The reduction in habitat effectiveness was estimated by buffering all proposed roads in each sub-watershed by a species-specific disturbance distance. Impacts to each species in each sub-watershed were assumed to occur in proportion to the amount of the sub-watershed that is within the overall range of the species. The amount of the reduction that would be attributable to well pads, roads, and compressors is likely overestimated slightly because of the overlap of buffers where roads are in close proximity; however, the estimate does not take into account any reduction in habitat effectiveness that might occur as a result of water handling facilities, which may compensate for this overestimate. The assumption was made that new oil and gas roads were proposed in inverse proportion to the presence of existing roads in each sub-watershed to calculate existing density of oil and gas roads that have not been mapped.

Several of the direct and indirect effects to big game would occur independently of the species in question and are discussed here. For several species, specific direct and indirect effects of concern were identified and are discussed in the section on each species that follows this general discussion of effects to big game.

Alternative 1

Hunting and Poaching

Many miles of new roads would be constructed as part of the proposed project (Table 2–5). These roads would provide increased access to both public and private lands in the Project Area. Because of this increased access, legal hunting pressure and poaching may intensify. Increased access to public lands would augment use by hunters of these areas; however, increased access for hunting is a management goal for many herd units (WGFD 2000a, 2000b). Private landowners would continue to control access to, and hunting on, split estate lands. Nevertheless, some increase in the level of poaching may occur because of the sparsely populated nature of the Project Area. This effect is expected to have minimal impact on big game because of the high proportion of private lands where new public access would not be created.

Vehicle Collisions

Increased vehicle traffic is anticipated in association with all phases of the project. The potential for vehicle collisions with big game would be directly correlated with the volume of traffic. The volume of project-related traffic is expected to be greatest during the construction phase and to gradually diminish during the production and decommissioning and abandonment phases. Speed limits set for project roads would reduce the potential for collisions; however, most collisions occur on county roads and highways, where speeds are higher and are regulated by the state, not [illegible]. Overall, a 25 percent or more increase in traffic is anticipated, which may result in additional collisions between big game and vehicles.

Loss or Degradation of Habitats

Habitat loss associated with construction and operation of facilities would result in a reduction of available forage and other habitat components in the affected area. Specific habitats that would be lost are discussed for each species below. Habitats adjacent to areas that are directly disturbed would be affected by changes in vegetation, including the potential invasion of noxious weeds. Alteration of ecological processes, such as the fire regime, may also affect habitat components that are important to big game. The exact location and concentration of this effect would vary depending on the timing and extent of development but is

BLANK PAGE

not expected to result in the alteration of seasonal habitat use or herd movements of big game within the Project Area. The direct loss of habitats would result in minor effects to big game because of the small proportion of the total amount of available habitats that would be affected; however, habitat loss may limit carrying capacity in areas of concentrated developments.

The direct loss of habitats caused by construction of water handling facilities would have negative effects to big game. Approximately 27,009 acres would be disturbed by water handling facilities under this alternative (Table 2-6). Construction of water handling facilities would generally occur in upland areas; however, the exact locations of these facilities are currently unknown. Because sagebrush shrublands and short- and mixed-grass habitats are the most common and widely distributed habitat types within the Project Area, it was assumed these habitat types would experience most of disturbance associated with construction of water handling facilities. However, construction of impoundments would be avoided in sagebrush shrubland habitats where practical.

Operation of water handling facilities may provide big game with new sources of drinking water and may increase the amount of forage available in wetland and riparian areas that expand in response to surface discharge of produced water and at LAD sites. As described in Chapter 2, quality of water discharged to the surface is strictly controlled by the NPDES permitting process. Discharged water would meet all NPDES permitting requirements and would not be harmful to big game. Water in containment reservoirs may not be suitable for use by big game because of the accumulation of salts and other toxic substances. Containment reservoirs would be fenced to exclude wildlife and livestock or designed and constructed to prevent entrapment and drowning.

The distribution of existing water resources combined with the new water handling facilities would not result in concentrations of big game or other wildlife to the extent that it would be detrimental to wildlife (for example, by promoting the spread of disease) or wildlife habitats (for example, through over-use of forage). Although water-handling facilities would not be specifically intended for use by wildlife or livestock, facilities that are not fenced to exclude wildlife and livestock would be designed and constructed to prevent entrapment or drowning.

Harassment and Displacement

Big game could be temporarily displaced from habitats in areas of human activity. The extent of displacement would depend on the presence of the animals, duration and intensity of the activity, and the sensitivity and habituation to disturbance of individual animals. Construction may result in displacement from affected habitats during the entire construction phase (a time frame of weeks to months); whereas production could result in displacement only during well visits (a time frame of hours). When they are displaced, individual animals would move to other adjacent habitats but may encounter competition for resources. Resources in avoided areas may be under-used, while resources could be over-used in areas where displaced animals take refuge. Displacement during the construction phase may alter patterns of habitat use and movements for individual animals, but would result in only minimal disruptions of seasonal habitat use or movement for entire herds because of the large areas occupied and the scattered nature of development. Displacement during the production phase would result in only minimal alteration of habitat use and movement patterns for both individual animals and entire herds because of habituation to regular disturbance (Yarmoloy et al. 1988). Nevertheless, the additive effect of many displacement events on big game could affect individual animals' health or condition, particularly in areas of concentrated development.

Noise

Noise is one factor in the displacement of big game from areas of otherwise suitable habitat and was considered as part of that analysis. Elevated levels of noise associated with increased human activity and facility operations may affect big game. The effects would depend on the occurrence pattern and intensity of produced noise. Big game responses may vary from tolerance to avoidance of affected habitats.

Dust

Dust would be generated and deposited on vegetation that provides forage for big game along existing and new roads within the Project Area. Deposition of road dust on vegetation can affect vegetation health, nutrition, and palatability. These effects are typically most severe immediately adjacent to roads, but can extend up to 0.5 mile away. Vegetation within these areas represents a relatively small proportion of the total available forage within a typical big game range. Habitats along roads are avoided because of the disturbance caused by vehicle traffic; therefore, the loss of forage productivity attributable to dust would have only minimal effects on big game because this forage is typically under-used.

Nutritional Status and Reproductive Success

Individual animals would expend additional energy in reacting to disturbances through physiological responses (increased heart rate) and physical responses (displacement) (Geist 1978). They would also have to move farther across the landscape to encounter the same amount of forage because of direct habitat loss. All of these factors have the potential to result in decreased nutritional status (for example, lower body fat), particularly during stressful periods or in ranges with poor quality and availability of forage (Hobbs 1989). Increased stress levels and decreased nutritional status have the potential to result in decreased reproductive success (Yarmoly et al. 1988). Decreased nutritional status reduces the ability of pregnant and lactating does and cows to provide the nutrition their fawns and calves need, which can lead directly to increased mortality of fawns and calves. Displacement can lead to separation of fawns and calves from does and cows, increasing mortality of fawns and calves through decreased nutritional status and increased predation. This consequence may affect individual animals or entire herds in areas of concentrated development and activity, or during periods of extreme stress, such as during a particularly cold and snowy winter.

Habitat Fragmentation

The pattern of well development for the proposed project would result in some degree of habitat fragmentation throughout the Project Area. The effects of habitat fragmentation and the subsequent suitability of big game ranges would depend upon several factors, including current range condition, carrying capacity, current population levels, species habitat requirements, degree of disturbance,

157

and availability of suitable habitats. The density of facilities in some portions of the Project Area may make these areas less available or fragmented to a degree that they would be unsuitable to several species of big game.

The pattern of fragmentation that would occur under this alternative would consist of the loss of narrow strips of habitats along roads, small patches at well pads and facility sites, and slightly larger patches around reservoirs and other water handling facilities. Habitat fragmentation is an issue to some wildlife species because of the creation of barriers between suitable and unsuitable habitats. These barriers often limit species occurrence and movement among habitats. Fragmentation would have minimal effects on big game because of their ability to move through and make use of the remaining habitats would not be affected.

A more important effect of this pattern of development is the loss of habitat effectiveness, as discussed above and shown on Table 4–29. Habitat effectiveness would be reduced because of the anticipated pattern of development. This pattern of development also would lead to the anticipated pattern of habitat fragmentation; however, the primary effect on big game would be the loss of habitat effectiveness, not habitat fragmentation.

Alternative 2A

Under Alternative 2A, the magnitude and type of effects would be similar to those presented under Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances. Approximately 36,263 acres would be disturbed by water handling facilities under this alternative (Table 2–23), an increase of 34 percent over the water handling disturbance associated with Alternative 1.

Alternative 2B

Under Alternative 2B, the magnitude and type of effects would be similar to those presented under Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances. Approximately 32,653 acres would be disturbed by water handling facilities under this alternative (Table 2–25), an increase of 21 percent over the water handling disturbance associated with Alternative 1.

Alternative 3

Under Alternative 3, the types of effects to big game would be similar to those presented for Alternative 1. The magnitude of these effects would be substantially smaller, however. Alternative 3 would result in the disturbance of 35 percent of the amount of wildlife habitats (Table 2–32) that would be affected under Alternatives 1, 2A, and 2B because the total number of new wells would be reduced to 40 percent (Table 2–29). The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller. Approximately 11,683 acres would be disturbed by water handling facilities under this alternative (Table 2–32), a decrease of 57 percent from the water handling disturbance associated with Alternative 1.

Pronghorn

Alternative 1

Fences

Barbed wire fences, which are common throughout the Project Area, can affect movements of pronghorn herds (Payne and Bryant 1994). New barbed wire fences would be constructed, primarily to keep wildlife and livestock out of construction, production, and water handling facility areas. These fences would enclose a small area and would not disrupt movement of pronghorn across the landscape. New fences would be constructed to meet BLM guidelines that are designed to reduce the potential for wildlife entanglement. New fences that cross large areas would not be constructed. Fences would have only minimal effects on pronghorn, associated with the low potential for entanglement, and may prevent injury or mortality by keeping animals away from construction, production, and water handling facilities.

Loss or Degradation of Habitats

Almost 161,400 acres of pronghorn ranges would be disturbed during the life of the project (Table 4-30 and Table 4-31). This acreage represents slightly more than 2 percent of the total areal extent of ranges present in the Project Area. Crucial winter-yearlong habitat would not be affected, less than 1 percent of severe winter and spring-summer-fall habitats would be affected, and between 2 and 3 percent of winter, winter-yearlong, and yearlong habitats would be affected. The amount of unreclaimed disturbance at any time during implementation of the project would be less than these estimates, because as new areas are disturbed by development, other areas would be undergoing interim reclamation after development is completed.

Habitat Effectiveness

Each of the direct and indirect impacts discussed above would reduce the ability of habitats to support pronghorn. Relatively little research on the effects of disturbance on pronghorn has been completed. The analysis of habitat effectiveness therefore assumed that they are similar to mule deer and reduce their use of habitats within one-eighth mile of disturbance (Rost and Bailey 1979). Table 4-29 shows the estimated reduction in habitat effectiveness for each alternative. Based on this reduction, the proposed project would cause a substantial decrease in the effectiveness of habitats in the Project Area for pronghorn, which may lower the population.

Population Effects

The effects of the proposed project on pronghorn populations are difficult to predict because of the many unknown factors associated with each of the potential effects and the potential for a synergistic relationship among the individual effects. The large scale and widespread nature of the anticipated impacts, particularly in terms of indirect impacts, suggest that some declines in pronghorn populations may occur. The degree of this potential decline is not known, but is not likely to occur to the extent that viability of the pronghorn population is compromised in the Project Area or across the range of the species as a whole.

159

Table 4-30 Direct Short-term and Long-term Effects to Pronghorn Ranges by Surface Owner — Alternative 1

Range	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Crucial Winter Yearlong	0	0	0	0	0	0	0	0	0	0	0	0
Severe Winter	0	0	0	0	19	16	0	0	9	7	28	24
Spring, Summer, Fall	51	21	8	7	0	0	6	5	418	175	483	208
Winter	764	297	0	0	0	0	226	99	2,470	1,134	3,460	1,530
Winter Yearlong	3,578	1,291	8	7	799	330	1,990	788	43,370	16,525	49,706	18,941
Yearlong	9,563	3,608	19	16	6,066	2,401	8,223	3,030	83,803	31,080	107,674	40,136
Total	13,956	5,218	36	31	6,884	2,748	10,438	3,921	130,077	48,920	161,371	60,837

Table 4-33 Direct Short-term and Long-term Effects to Pronghorn Ranges by Sub-watershed – Alternative 1

Sub-watershed	Range (acres)													
	Crucial Winter Yearlong		Severe Winter		Spring, Summer, Fall		Winter		Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	0	0	0	0	0	0	0	0	550	179	6,678	2,417	7,168	2,596
Middle Fork Powder River	0	0	0	0	14	12	0	0	22	19	3	2	39	33
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	3	2	3	2
Upper Powder River	0	0	0	0	3	2	2,777	1,023	20,322	7,396	23,156	8,412	46,257	16,832
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	8	7	8	7
Salt Creek	0	0	0	0	14	12	0	0	388	139	177	78	579	229
Crazy Woman Creek	0	0	0	0	0	0	0	0	3	2	11,368	3,985	11,371	3,987
Clear Creek	0	0	0	0	0	0	0	0	2,011	726	8,611	3,122	10,622	3,848
Middle Powder River	0	0	0	0	452	180	129	58	0	0	2,406	986	2,988	1,224
Little Powder River	0	0	0	0	0	0	575	451	5,948	2,652	9,249	4,269	15,772	7,372
Little Missouri River	0	0	0	0	0	0	0	0	8	7	217	186	226	193
Antelope Creek	0	0	14	12	0	0	0	0	2,081	735	36,481	12,962	38,576	13,709
Dry Fork Cheyenne River	0	0	14	12	0	0	0	0	25	21	96	82	135	115
Upper Cheyenne River	0	0	0	0	0	0	0	0	1,345	497	1,837	737	3,182	1,234
Lightning Creek	0	0	0	0	0	0	0	0	11	9	124	106	135	115
Upper Belle Fourche River	0	0	0	0	0	0	0	0	16,957	6,499	7,049	2,757	24,006	9,256
Middle North Platte River	0	0	0	0	0	0	0	0	76	63	30	26	105	89
Total	0	0	28	24	483	206	3,481	1,531	49,786	18,941	107,674	40,176	161,371	60,877

BEST COPY AVAILABLE

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

Alternative 2B

Under Alternative 2B, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

Alternative 3

Under Alternative 3, the types of effects to pronghorn would be similar to those presented for Alternative 1. The magnitude of these effects would be smaller; however, Alternative 3 would result in the disturbance of approximately 42 percent of the amount of pronghorn habitats that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent (Table 2-29). Table 4-32 and Table 4-33 show estimates of disturbance to pronghorn ranges for Alternative 3 by surface owner and sub-watershed. Each of the effects discussed for Alternative 1 would still occur; however, fewer individual pronghorn would be affected and any effects on herds would be reduced. The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller, as discussed for big game species above. The overall effect on pronghorn populations in the Project Area would also be reduced.

White-tailed Deer

Alternative 1

Loss or Degradation of Habitats

There are approximately 766,000 acres of white-tailed deer ranges in the Project Area (Chapter 3 Wildlife). Approximately 9,800 acres of white-tailed deer ranges would be disturbed during the life of the project under Alternative 1 (Table 4-34 and Table 4-35). Less than one-half of 1 percent of winter-yearlong habitat and slightly more than 1 percent of yearlong habitat would be affected. These estimates represent the maximum disturbance that would occur during the life of the project. The amount of unreclaimed disturbance at any one time during project implementation would be less than these estimates, because as new areas are disturbed by development, other areas would be undergoing interim reclamation after development is completed.

BLANK PAGE

Table 4-32 Direct Short-term and Long-term Effects to Pronghorn Ranges by Surface Owner — Alternative 3

Range	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Crucial Winter Yearlong	0	0	0	0	0	0	0	0	0	0	0	0
Severe Winter	0	0	0	0	0	0	0	0	3	2	3	2
Spring, Summer, Fall	0	0	0	0	0	0	0	0	56	26	56	26
Winter	0	0	0	0	0	0	220	99	574	288	794	387
Winter Yearlong	0	0	0	0	116	52	1,764	706	19,860	7,705	21,740	8,463
Yearlong	3	2	0	0	1,045	388	7,757	2,862	36,331	13,421	45,135	16,673
Total	3	2	0	0	1,161	440	9,741	3,667	56,824	21,442	67,729	25,551

163

Table 4–33 Direct Short-term and Long-term Effects to Pronghorn Ranges by Sub-watershed – Alternative 3

Sub-watershed	Range (acres)													
	Crucial Winter Yearlong		Severe Winter		Spring, Summer, Fall		Winter		Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	0	0	0	0	0	0	0	0	405	141	5,966	2,158	6,371	2,299
Middle Fork Powder River	0	0	0	0	0	0	0	0	8	7	3	2	11	9
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
Upper Powder River	0	0	0	0	0	0	535	202	5,285	1,953	6,230	2,265	12,050	[illegible]
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	8	7	8	7
Salt Creek	0	0	0	0	6	5	0	0	260	90	128	49	394	[illegible]
Crazy Woman Creek	0	0	0	0	0	0	0	0	0	0	3,726	1,303	3,726	1,303
Clear Creek	0	0	0	0	0	0	0	0	1,441	520	5,793	2,045	7,235	2,565
Middle Powder River	0	0	0	0	51	21	29	16	0	0	441	197	521	233
Little Powder River	0	0	0	0	0	0	229	169	2,842	1,268	4,443	1,900	7,514	3,338
Little Missouri River	0	0	0	0	0	0	0	0	0	0	66	56	66	56
Antelope Creek	0	0	0	0	0	0	0	0	1,098	387	12,726	4,508	13,823	4,895
Dry Fork Cheyenne River	0	0	3	2	0	0	0	0	11	9	30	26	44	38
Upper Cheyenne River	0	0	0	0	0	0	0	0	682	257	752	303	1,434	560
Lightning Creek	0	0	0	0	0	0	0	0	8	7	61	52	69	59
Upper Belle Fourche River	0	0	0	0	0	0	0	0	9,670	3,798	4,745	1,788	14,415	5,586
Middle North Platte River	0	0	0	0	0	0	0	0	30	26	17	14	47	40
Total	0	0	3	2	56	26	794	387	21,740	8,463	45,135	16,673	67,729	25,551

BEST COPY AVAILABLE

164

Table 4–34 Direct Short-term and Long-term Effects to White-tailed Deer Ranges by Surface Owner — Alternative 1

	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
Range	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Winter Yearlong	0	0	0	0	0	0	0	0	19	16	19	16
Yearlong	354	138	0	0	96	43	800	298	8,530	3,297	9,780	3,776
Total	354	138	0	0	96	43	800	298	8,549	3,313	9,800	3,793

Table 4-35 Direct Short-term and Long-term Effects to White-tailed Deer Ranges by Sub-watershed — Alternative 1

Sub-watershed	Range (acres)					
	Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	8	7	8	7
Upper Tongue River	0	0	2,880	1,062	2,880	1,062
Middle Fork Powder River	0	0	8	7	8	7
North Fork Powder River	0	0	0	0	0	0
Upper Powder River	0	0	2,062	744	2,062	744
South Fork Powder River	0	0	3	2	3	2
Salt Creek	0	0	0	0	0	0
Crazy Woman Creek	0	0	643	222	643	222
Clear Creek	0	0	2,717	936	2,717	936
Middle Powder River	19	16	46	19	66	36
Little Powder River	0	0	1,060	626	1,060	626
Little Missouri River	0	0	0	0	0	0
Antelope Creek	0	0	236	86	236	86
Dry Fork Cheyenne River	0	0	6	5	6	5
Upper Cheyenne River	0	0	0	0	0	0
Lightning Creek	0	0	0	0	0	0
Upper Belle Fourche River	0	0	111	60	111	60
Middle North Platte River	0	0	0	0	0	0
Total	19	16	9,780	3,776	9,800	3,793

BLANK PAGE

Habitat Effectiveness

Each of the direct and indirect impacts discussed above would reduce the ability of habitats to support white-tailed deer. The analysis of habitat effectiveness therefore assumed that white-tailed deer are similar to mule deer and reduce their use of habitats within one-eighth mile of disturbance (Rost and Bailey 1979). Table 4-28 shows the estimated reduction in habitat effectiveness for each alternative. Based on this reduction, the proposed project would cause a minor decrease in the effectiveness of habitats in the Project Area for white-tailed deer, which may result in a small decrease in population.

Population Effects

The effects of the proposed project on populations of white-tailed deer are difficult to predict because of the many unknown factors associated with each of the potential effects and the potential for a synergistic relationship among the individual effects. The moderate scale and widespread nature of the anticipated impacts, particularly in terms of indirect impacts, suggest that some declines in populations of white-tailed deer may occur. The degree of this potential decline is not known, but is not likely to occur to the extent that viability of the population of white-tailed deer is compromised in the Project Area or across the range of the species as a whole.

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

Alternative 2B

Under Alternative 2B, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

Alternative 3

Under Alternative 3, the types of effects to white-tailed deer would be similar to those presented for Alternative 1. The magnitude of these effects would be substantially smaller, however. Alternative 3 would result in the disturbance of 78 percent of the amount of white-tailed deer habitats that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent (Table 2–29). Table 4–36 and Table 4–37 show estimates of disturbance to white-tailed deer ranges for Alternative 3 by surface owner and sub-watershed. Each of the effects discussed for Alternative 1 would still occur; however, fewer individual white-tailed deer would be affected and any effects on herds would be reduced. The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller, as discussed for big game species above. The overall effect on populations of white-tailed deer in the Project Area would also be reduced.

167

Table 4-36 Direct Short-term and Long-term Effects to White-tailed Deer Ranges by Surface Owner — Alternative 3

Range	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Winter Yearlong	0	0	0	0	0	0	0	0	11	9	11	9
Yearlong	0	0	0	0	8	7	800	298	6,802	2,560	7,610	2,864
Total	0	0	0	0	8	7	800	298	6,813	2,569	7,621	2,874

Table 4-37 Direct Short-term and Long-term Effects to White-tailed Deer Ranges by Sub-watershed — Alternative 3

Sub-watershed	Range (acres)					
	Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	8	7	8	7
Upper Tongue River	0	0	2,791	1,030	2,791	1,030
Middle Fork Powder River	0	0	6	5	6	5
North Fork Powder River	0	0	0	0	0	0
Upper Powder River	0	0	1,215	444	1,215	444
South Fork Powder River	0	0	3	2	3	2
Salt Creek	0	0	0	0	0	0
Crazy Woman Creek	0	0	314	111	314	111
Clear Creek	0	0	2,403	832	2,403	832
Middle Powder River	11	9	18	6	29	16
Little Powder River	0	0	665	347	665	347
Little Missouri River	0	0	0	0	0	0
Antelope Creek	0	0	103	36	103	36
Dry Fork Cheyenne River	0	0	3	2	3	2
Upper Cheyenne River	0	0	0	0	0	0
Lightning Creek	0	0	0	0	0	0
Upper Belle Fourche River	0	0	82	41	82	41
Middle North Platte River	0	0	0	0	0	0
Total	11	9	7,610	2,864	7,621	2,874

Mule Deer

Alternative 1

Loss or Degradation of Habitats

Approximately 134,133 acres of mule deer ranges would be disturbed during the life of the project under Alternative 1 (Table 4–38 and Table 4–39). This acreage represents slightly less than 2 percent of the total amount of ranges in the Project Area. Slightly less than 2 percent of winter-yearlong habitat would be disturbed during the life of the project. Two percent of yearlong range would be disturbed. Only one-tenth of 1 percent of spring, summer, and fall range would be disturbed under Alternative 1. These estimates represent the maximum disturbance that would occur during the life of the project. The amount of unreclaimed disturbance at any time during project implementation would be less than these estimates, because as new areas are disturbed by development, other areas would be undergoing interim reclamation after development is completed.

Habitat Effectiveness

Each of the direct and indirect effects discussed above would reduce the ability of habitats to support mule deer. Existing literature was used for the analysis of habitat effectiveness (Rost and Bailey 1979), which shows that mule deer reduce their use of habitats within one-eighth mile of disturbance. Table 4–28 shows the estimated reduction in habitat effectiveness for each alternative. Based on this reduction, the proposed project would cause a decrease in the effectiveness of habitats in the Project Area for mule deer, which may result in a decrease in the population.

Population Effects

The effects of the proposed project on mule deer populations are difficult to predict because of the many unknown factors associated with each of the potential effects and the potential for a synergistic relationship among the individual effects. The large scale and widespread nature of the anticipated effects , particularly in terms of indirect effects, suggest that some declines in mule deer populations may occur. The degree of this potential decline is not known, but is not likely to occur to the extent that viability of the mule deer population is compromised in the Project Area or across the range of the species as a whole.

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various methods used to handle produced water and their associated disturbances, as discussed for big game species above.

Alternative 2B

Under Alternative 2B, the magnitude and type of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

BLANK PAGE

Table 4–38 Direct Short-term and Long-term Effects to Mule Deer Ranges by Surface Owner — Alternative 1

Range	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Spring, Summer, Fall	6	5	0	0	0	0	0	0	11	9	17	14
Winter Yearlong	12,845	4,790	11	9	577	467	5,002	1,897	50,369	19,204	68,804	26,367
Yearlong	5,605	2,104	25	21	1,256	483	3,060	1,182	55,367	20,924	65,313	24,715
Total	18,456	6,899	36	31	1,832	950	8,062	3,079	105,748	40,137	134,133	51,096

(7)

Table 4–39 Direct Short-term and Long-term Effects to Mule Deer Ranges by Sub-watershed — Alternative 1

Sub-watershed	Range (acres)							
	Spring, Summer, Fall		Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	14	12	0	0	14	12
Upper Tongue River	0	0	7,428	2,688	22	19	7,450	2,707
Middle Fork Powder River	14	12	52	45	0	0	66	56
North Fork Powder River	0	0	0	0	3	2	3	2
Upper Powder River	0	0	33,032	12,014	20,650	7,515	53,682	19,530
South Fork Powder River	0	0	6	5	3	2	8	7
Salt Creek	0	0	992	358	169	72	1,161	430
Crazy Woman Creek	0	0	8,249	2,893	3,125	1,096	11,374	3,990
Clear Creek	3	2	10,802	3,823	1,029	372	11,834	4,198
Middle Powder River	0	0	2,416	1,013	807	327	3,224	1,340
Little Powder River	0	0	4,667	2,925	8,197	3,472	12,863	6,397
Little Missouri River	0	0	259	221	0	0	259	221
Antelope Creek	0	0	803	298	19,566	6,976	20,369	7,274
Dry Fork Cheyenne River	0	0	36	31	99	85	135	115
Upper Cheyenne River	0	0	0	0	1,159	476	1,159	476
Lightning Creek	0	0	14	12	121	103	135	115
Upper Belle Fourche River	0	0	6	5	10,289	4,133	10,294	4,138
Middle North Platte River	0	0	30	26	74	63	105	89
Total	17	14	68,804	26,367	65,313	24,715	134,133	51,096

BLANK PAGE

Alternative 3

Under Alternative 3, the types of effects to mule deer would be similar to those presented for Alternative 1. The magnitude of these effects would be a lot smaller; however. Alternative 3 would result in the disturbance of 38 percent of the amount of mule deer habitats that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent (Table 2–29). Table 4–40 and Table 4–41 show estimates of disturbance to mule deer ranges for Alternative 3 by surface owner and sub-watershed. Each of the effects discussed for Alternative 1 would still occur; however, fewer individual mule deer would be affected, and any effects on herds would be reduced. The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller, as discussed for big game species above. The overall effect on mule deer populations in the Project Area would also be reduced.

Elk

Alternative 1

Loss or Degradation of Habitats

This analysis applies primarily to elk and elk ranges that occur within the Fortification Creek area in the Upper Powder River sub-watershed. This area contains several overlapping elk ranges and is expected to experience disturbance from the construction and operation of CBM wells, non-CBM wells, compressors, and water handling facilities. Elk ranges exist outside of the Fortification Creek area along the southern and western boundaries of the Project Area but would be disturbed only by the construction of non-CBM wells. The total disturbance in these ranges outside of Fortification Creek would be 160 acres out of 610,000 acres of ranges. These disturbances are presented in Table 4–42 and Table 4–43 for surface owner and sub-watersheds. The level of disturbance to elk and their ranges outside of Fortification Creek would not result in detrimental effects to seasonal habitat use, herd movements, or herd condition because of the small proportion (less than one-tenth of 1 percent) of habitats that would be disturbed.

There are approximately 122,931 acres of elk ranges in the Fortification Creek area. Because of overlap, it is not appropriate to sum the totals of each range to estimate the total acres of range within this area. Crucial winter, parturition, winter yearlong, and yearlong ranges occur with varying degrees of overlap in the Fortification Creek area. Estimated disturbances to each range type within the Fortification Creek area are presented by surface owner in Table 4–44. All disturbances to the Fortification Creek area would occur in the Upper Powder River sub-watershed. The greatest proportion of disturbance to a single range type would be 4 percent for yearlong range. Approximately 1 percent of crucial winter and parturition ranges and 2 percent of winter yearlong range would be disturbed over the life of the project. These estimates represent the maximum disturbance that would occur during the life of the project. The amount of unreclaimed disturbance at any time during project implementation would be less than these estimates, because as new areas are disturbed by development, other areas would be undergoing interim reclamation after development is completed.

BEST COPY AVAILABLE

Table 4–40 Direct Short-term and Long-term Effects to Mule Deer Ranges by Surface Owner — Alternative 3

	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
Range	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Spring, Summer, Fall	0	0	0	0	0	0	0	0	6	5	6	5
Winter Yearlong	3	2	0	0	63	54	4,860	1,838	21,578	8,131	26,504	10,025
Yearlong	0	0	0	0	72	32	2,922	1,122	21,230	8,037	24,224	9,191
Total	3	2	0	0	136	86	7,783	2,959	42,813	16,173	50,734	19,220

Table 4-41 Direct Short-term and Long-term Effects to Mule Deer Ranges by Sub-watershed — Alternative 3

Sub-watershed	Range (acres)							
	Spring, Summer, Fall		Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	14	12	0	0	14	12
Upper Tongue River	0	0	6,579	2,372	17	14	6,595	2,386
Middle Fork Powder River	3	2	19	16	0	0	22	19
North Fork Powder River	0	0	0	0	0	0	0	0
Upper Powder River	0	0	7,011	2,557	5,205	1,921	12,216	4,479
South Fork Powder River	0	0	6	5	3	2	8	7
Salt Creek	0	0	458	162	104	41	562	202
Crazy Woman Creek	0	0	2,409	841	1,320	465	3,729	1,306
Clear Creek	3	2	7,386	2,605	704	255	8,092	2,863
Middle Powder River	0	0	285	134	265	115	550	249
Little Powder River	0	0	1,879	1,083	3,040	1,264	4,919	2,347
Little Missouri River	0	0	91	78	0	0	91	78
Antelope Creek	0	0	322	120	7,354	2,605	7,675	2,724
Dry Fork Cheyenne River	0	0	14	12	30	26	44	38
Upper Cheyenne River	0	0	0	0	546	235	546	235
Lightning Creek	0	0	6	5	63	54	69	59
Upper Belle Fourche River	0	0	6	5	5,550	2,173	5,555	2,177
Middle North Platte River	0	0	22	19	25	21	47	40
Total	6	5	26,504	10,025	24,224	9,191	50,734	19,220

Table 4–42 Direct Short-term and Long-term Effects to Elk Ranges (excluding Fortification Creek) by Surface Owner — Alternative 1

	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
Range	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Crucial Winter	0	0	0	0	0	0	3	2	0	0	3	2
Crucial Winter Yearlong	6	5	0	0	0	0	8	7	8	7	22	19
Spring, Summer, Fall	3	2	0	0	0	0	0	0	6	5	8	7
Winter	0	0	0	0	0	0	0	0	8	7	8	7
Winter Yearlong	0	0	0	0	6	5	0	0	6	5	11	9
Yearlong	6	5	14	12	19	16	3	2	66	56	107	92
Total	14	12	14	12	25	21	14	12	94	80	160	136

Table 4-43 Direct Short-term and Long-term Effects to Elk Ranges (excluding Fortification Creek) by Sub-watershed — Alternative 1

	Range (acres)													
	Crucial Winter		Crucial Winter Yearlong		Spring, Summer, Fall		Winter		Winter Yearlong		Yearlong		Total	
Sub-watershed	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	3	2	0	0	0	0	0	0	0	0	0	0	3	2
Middle Fork Powder River	0	0	22	19	6	5	0	0	0	0	0	0	28	24
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	3	2	3	2
Upper Powder River	0	0	0	0	0	0	0	0	0	0	19	16	19	16
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	3	2	3	2
Salt Creek	0	0	0	0	0	0	0	0	0	0	14	12	14	12
Crazy Woman Creek	0	0	0	0	0	0	3	2	0	0	0	0	3	2
Clear Creek	0	0	0	0	3	2	6	5	0	0	0	0	8	7
Middle Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Missouri River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antelope Creek	0	0	0	0	0	0	0	0	3	2	25	21	28	24
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cheyenne River	0	0	0	0	0	0	0	0	8	7	39	33	47	40
Lightning Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Belle Fourche River	0	0	0	0	0	0	0	0	0	0	6	5	6	5
Middle North Platte River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3	2	22	19	8	7	8	7	11	9	107	92	160	136

BEST COPY AVAILABLE

177

Table 4-44 Direct Short-term and Long-term Effects to Elk Ranges (Fortification Creek only) by Surface Owner — Alternative 1

	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
Range	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Crucial Winter	183	69	0	0	0	0	74	28	578	216	835	313
Parturition	649	240	0	0	0	0	119	45	723	273	1,491	557
Winter Yearlong	1,038	375	0	0	0	0	252	91	1,050	388	2,341	854
Yearlong	1,963	717	0	0	0	0	327	118	2,020	746	4,310	1,580

BLANK PAGE

Habitat Effectiveness

Each of the direct and indirect effects discussed above would reduce the ability of habitats to support elk. Numerous studies suggest that elk move considerable distances to avoid disturbance (Cole et al. 1997, Edge and Marcum 1985, Lyon 1979, Perry and Overly 1976, Rowland et al. 2000, Ward 1976). Existing literature was used in the analysis of habitat effectiveness (Lyon 1979, Ward 1976), which shows that elk reduce their use of habitats within one-half mile of disturbance. Table 4–28 shows the estimated reduction in habitat effectiveness for each sub-watershed by each alternative. Based on this reduction, the proposed project would cause a moderate decrease in the effectiveness of habitats in the Project Area for elk, which may result in decreased population. The effect of oil and gas development may be more severe within herd management units that support elk populations that are at or near carrying capacity.

Population Effects

The effects of the proposed project on elk populations are difficult to predict because of the many unknown factors associated with each of the potential effects and the potential for a synergistic relationship among the individual effects. The moderate scale and spatially limited nature of the anticipated impacts, particularly in terms of indirect impacts, suggest that some declines in elk populations may occur. The degree of this potential decline is not known, but is not likely to occur to the extent that viability in the elk population is compromised in the Project Area or across the range of the species as a whole.

Alternative 2A

Under Alternative 2A, the magnitude and type of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

Alternative 2B

Under Alternative 2B, the magnitude and type of effects would be similar to those presented for Alternative 1, with the exception of the contribution of disturbance associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances, as discussed for big game species above.

Alternative 3

Under Alternative 3, the types of effects to elk would be similar to those presented for Alternative 1. The magnitude of these effects would be considerably smaller. Alternative 3 would result in the disturbance of 16 percent of the amount of elk habitats that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent (Table 2–29). Table 4–45 and Table 4–46 show estimates of disturbance to elk ranges for Alternative 3 outside of the Fortification Creek area by surface owner and sub-watershed. Table 4–47 shows estimates of disturbance to elk ranges for Alternative 3 in the Fortification Creek area by surface owner. All disturbances to the Fortification Creek area would occur in the Upper Powder River sub-watershed.

Table 4–45 Direct Short-term and Long-term Effects to Elk Ranges (excluding Fortification Creek) by Surface Owner — Alternative 3

	Surface Owner (acres)											
	BLM											
	BFO		CFO		FS		State		Private		Total	
Range	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Crucial Winter Yearlong	0	0	0	0	0	0	0	0	3	2	3	2
Crucial Winter	0	0	0	0	0	0	3	2	0	0	3	2
Spring, Summer, Fall	0	0	0	0	0	0	0	0	3	2	3	2
Winter	0	0	0	0	0	0	0	0	6	5	6	5
Winter Yearlong	0	0	0	0	0	0	0	0	0	0	0	0
Yearlong	0	0	0	0	0	0	3	2	17	14	19	16
Total	0	0	0	0	0	0	6	5	28	24	33	28

Table 4–46 Direct Short-term and Long-term Effects to Elk Ranges (excluding Fortification Creek) by Sub-watershed — Alternative 3

Sub-watershed	Range (acres)													
	Crucial Winter Yearlong		Crucial Winter		Spring, Summer, Fall		Winter		Winter Yearlong		Yearlong		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	3	2	3	2	0	0	0	0	0	0	0	0	6	5
Middle Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	0	0	0	0	0	0	0	0	0	0	3	2	3	2
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	3	2	3	2
Salt Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crazy Woman Creek	0	0	0	0	0	0	3	2	0	0	0	0	3	2
Clear Creek	0	0	0	0	3	2	3	2	0	0	0	0	6	5
Middle Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Missouri River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antelope Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cheyenne River	0	0	0	0	0	0	0	0	0	0	8	7	8	7
Lightning Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Belle Fourche River	0	0	0	0	0	0	0	0	0	0	6	5	6	5
Middle North Platte River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3	2	3	2	3	2	6	5	0	0	19	16	33	28

Table 4–47 Direct Short-term and Long-term Effects to Elk Ranges (Fortification Creek only) by Surface Owner — Alternative 3

Range	Surface Owner (acres)											
	BLM											
	Buffalo FO		Casper FO		FS		State		Private		Total	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Crucial Winter Range	0	0	0	0	0	0	74	28	45	18	120	46
Parturition	0	0	0	0	0	0	119	45	34	15	154	60
Winter Yearlong	0	0	0	0	0	0	252	91	85	32	337	123
Yearlong	0	0	0	0	0	0	327	118	366	135	693	253

BEST COPY AVAILABLE

[illegible]

BLANK PAGE

Each of the effects discussed for Alternative 1 would still occur; however, fewer individual elk would be affected and any effects on herds would be reduced. The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller, as discussed for big game species above. The overall effect on elk populations in the Project Area would also be reduced.

Moose

Under each of the four alternatives, activities associated with the project would not affect any of the five moose ranges that occur in the Project Area and are not expected to have any effects on individual moose or moose populations.

Cumulative Effects

Implementation of each of the alternatives would contribute to cumulative effects to big game species in the Project Area. Cumulative short- and long-term disturbance to big game species by alternative and sub-watershed are presented for pronghorn in Table 4–48, for white-tailed deer in Table 4–49, for mule deer in Table 4–50, and for elk in Table 4–51. The cumulative effects are presented as a percentage of the amount of habitats for each species in each sub-watershed. Existing and proposed disturbance from project activities, including water handling, were included in the calculations. For water handling disturbance, an assumption was made that each big game range would be disturbed in proportion to its extent in each sub-watershed. Additional oil and gas development (conventional and CBM) may occur later beyond the level of development considered in this analysis. The data for Alternative 3 do not include potential new federal wells that would be developed in response to drainage caused by production on adjacent state or fee minerals. Other activities that contribute to cumulative effects to wildlife in the Project Area include coal mining; uranium mining; sand, gravel, and scoria mining; ranching; agriculture; road and railroad construction; and rural and urban housing development. The cumulative effects of these impacts on wildlife habitats are discussed in the section on Vegetation.

The total acreage affected by development of CBM would not be disturbed simultaneously because development would occur over the life of the project. Some of the disturbed acreage would be reclaimed or would be in the process of being reclaimed when new disturbances are initiated. Development of CBM is expected to occur at a rate faster than abandonment and reclamation of wells. In the near future, the amount of disturbed habitats is likely to increase, although the anticipated life of CBM wells indicates that reclamation would eventually overtake development of new wells, resulting in a net decrease in disturbed vegetation for the long term. In areas reclaimed after development of CBM, vegetation often differs from undisturbed areas, as discussed in the section on Vegetation. As a result, shifts in habitat composition or distribution could affect big game species within the Project Area.

183

Table 4–48 **Cumulative Habitat Disturbance for Pronghorn by Sub-watershed and Alternative (calculated as a percentage of the total extent of pronghorn ranges in the Project Area)**

Sub-watershed	Alternative 1		Alternative 2A		Alternative 2B		Alternative 3	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Tongue River	1.8	1.0	1.9	1.1	1.8	1.0	1.6	0.8
Middle Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Powder River	4.4	2.3	4.8	2.7	4.7	2.6	1.5	0.9
South Fork Powder River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt Creek	0.5	0.2	0.5	0.2	0.5	0.2	0.3	0.2
Crazy Woman Creek	2.7	1.2	2.9	1.5	2.9	1.4	0.9	0.4
Clear Creek	3.0	1.5	3.1	1.7	3.0	1.6	2.0	1.0
Middle Powder River	4.1	3.1	4.2	3.2	4.2	3.2	2.4	2.3
Little Powder River	3.5	2.4	3.6	2.4	3.5	2.4	2.3	1.7
Little Missouri River	0.8	0.7	0.8	0.7	0.8	0.7	0.3	0.3
Antelope Creek	6.5	2.7	6.4	2.7	6.4	2.7	2.6	1.2
Dry Fork Cheyenne River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Upper Cheyenne River	2.8	1.7	2.8	1.7	2.8	1.7	1.8	1.3
Lightning Creek	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Upper Belle Fourche River	5.5	3.7	5.4	3.6	5.4	3.6	4.1	3.0
Middle North Platte River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	3.3	1.8	3.4	2.0	3.4	1.9	1.7	1.1

Table 4-49 **Cumulative Habitat Disturbance for White-tailed Deer by Sub-watershed and Alternative (calculated as a percentage of the total extent of white-tailed deer ranges in the Project Area)**

Sub-watershed	Alternative							
	1		2A		2B		3	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Upper Tongue River	1.6	0.9	1.7	1.0	1.6	0.9	1.5	0.8
Middle Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Powder River	4.6	2.7	5.0	3.1	4.9	3.0	2.9	1.8
South Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salt Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crazy Woman Creek	1.4	0.8	1.7	1.1	1.6	1.0	0.7	0.4
Clear Creek	2.9	1.6	3.1	1.7	3.0	1.6	2.5	1.3
Middle Powder River	1.0	0.8	1.1	0.9	1.1	0.9	0.5	0.5
Little Powder River	1.6	1.1	1.6	1.2	1.6	1.1	1.1	0.8
Little Missouri River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antelope Creek	1.6	0.7	1.5	0.7	1.5	0.7	0.7	0.3
Dry Fork Cheyenne River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Upper Cheyenne River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lightning Creek	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Upper Belle Fourche River	2.0	1.6	1.9	1.5	1.9	1.5	1.5	1.2
Middle North Platte River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.9	1.1	2.0	1.2	2.0	1.2	1.4	0.8

BEST COPY AVAILABLE

185

Table 4–50 Cumulative Habitat Disturbance for Mule Deer by Sub-watershed and Alternative (calculated as a percentage of the total extent of mule deer ranges in the Project Area)

	Alternative							
	1		2A		2B		3	
Sub-watershed	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Tongue River	1.5	0.8	1.6	0.9	1.5	0.8	1.3	0.7
Middle Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Powder River	4.5	2.3	4.9	2.7	4.8	2.6	1.3	0.8
South Fork Powder River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt Creek	0.9	0.4	0.9	0.4	0.9	0.4	0.4	0.2
Crazy Woman Creek	2.5	1.1	2.7	1.4	2.7	1.3	0.8	0.4
Clear Creek	2.9	1.5	3.1	1.7	2.9	1.5	2.0	1.0
Middle Powder River	3.4	2.6	3.5	2.6	3.5	2.6	2.0	1.8
Little Powder River	2.9	2.0	2.9	2.0	2.8	2.0	1.7	1.4
Little Missouri River	0.8	0.7	0.8	0.7	0.8	0.7	0.3	0.3
Antelope Creek	3.9	1.7	3.9	1.7	3.9	1.7	1.6	0.8
Dry Fork Cheyenne River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Upper Cheyenne River	1.7	1.2	1.7	1.2	1.6	1.2	1.2	0.9
Lightning Creek	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Upper Belle Fourche River	4.5	3.1	4.4	3.0	4.4	3.0	3.2	2.4
Middle North Platte River	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	2.6	1.5	2.7	1.6	2.7	1.5	1.3	0.8

Table 4–51 Cumulative Habitat Disturbance for Elk (excluding Fortification Creek) by Sub-watershed and Alternative (calculated as a percentage of the total extent of elk ranges in the Project Area)

Sub-watershed	Alternative							
	1		2A		2B		3	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Little Bighorn River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Tongue River	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3
Middle Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Fork Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Powder River	0.9	0.9	1.3	1.3	1.2	1.2	0.3	0.3
South Fork Powder River	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Salt Creek	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Crazy Woman Creek	0.4	0.4	0.6	0.6	0.6	0.6	0.1	0.1
Clear Creek	0.7	0.7	0.8	0.8	0.7	0.7	0.5	0.4
Middle Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Little Powder River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Little Missouri River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antelope Creek	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
Dry Fork Cheyenne River	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Upper Cheyenne River	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
Lightning Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Belle Fourche River	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4
Middle North Platte River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.5	0.5	0.6	0.6	0.6	0.6	0.3	0.3

BEST COPY AVAILABLE

187

Raptors

A variety of raptors inhabits the Project Area and makes use of all habitats present. Several of these species are discussed in the section on Threatened, Endangered, or Sensitive Species. The effects to general raptor habitats are essentially the same as effects to vegetation. Possible effects to raptors include: increased direct mortality (including poaching, collisions with power lines and vehicles, and electrocution on power lines); the introduction of new perches; direct loss or degradation of habitats; indirect disturbance from human activity (including harassment, displacement, noise, and degradation or loss of habitats important to prey species); habitat fragmentation; and changes in population levels. Each of these effects is discussed below.

Alternative 1

Direct Mortality

Raptors may be affected in several ways. Construction would not cause direct injury or mortality because raptors would avoid disturbance associated with construction. Mitigation measures included as part of the proposed project would limit activities in nesting habitats, further minimizing the potential for direct injury or mortality to individual raptors. Poaching, vehicle collision, and collision with and electrocution by power lines could cause direct mortality of raptors. Any mortality of raptors would be in violation of the Migratory Bird Treaty Act (MBTA).

Many miles of new roads would be constructed as part of the proposed project (Table 2–5). These roads would increase access to public lands in the Project Area. Because of this increase in access, illegal shooting of raptors also may increase. However, any increase in illegal shooting is expected to have minimal effect on raptors because of the high proportion of private lands where new public access would not be created.

Increased vehicle traffic is anticipated in association with all phases of the project. The literature on avian mortality caused by collision with vehicles is reviewed by Erickson et al. (2001). Most birds killed by vehicle collision are passerines, although raptors, particularly owls, are also killed. Raptors may be struck by vehicles while they hunt or feed on carrion near roads. Most raptors do not focus their foraging efforts on carrion (Ehrlich et al. 1988), however, reducing their potential for being struck by vehicles along roads. The potential for vehicle collisions would be directly correlated with the volume of traffic. Project-related traffic is expected to be greatest during the construction phase and to gradually diminish during the production and reclamation/abandonment phases. The use of speed limits on project roads would reduce the potential for collisions; however, most collisions occur on county roads and highways, where speeds are higher and are regulated by the state, not BLM. Foraging raptors tend to avoid areas of heavy traffic, further reducing their potential for being struck by vehicles on busy roads. Overall, a 25 percent or more increase in traffic is anticipated (Chapter 4, Transportation), which may result in a similar increase in mortality to raptors. This increase would be in addition to a reported doubling (from 17 to 32) in raptor collisions since large-scale development of CBM began in the Project Area

(Seacross 2002). This impact is not expected to have a substantial effect on raptor populations because of the low incidence of mortalities from vehicle collisions, compared with the relatively large size of the raptor population in the Project Area.

The presence of new aboveground power lines may increase the potential for raptor collisions. The literature on avian mortality caused by collision with power lines is reviewed by Erickson et al. (2001). Water birds and waterfowl are the most common groups of birds killed by collision with power lines. Raptors also collide with power lines; however, the proportion of raptor mortalities attributed to collision is minimal compared with mortalities attributed to electrocutions (Erickson et al. 2001). Specific measures that would help reduce the potential for raptor collision with power lines, such as burying lines where feasible and avoiding areas of high avian use (wetlands, prairie dog towns, and grouse leks), would be implemented. This impact is not expected to have a considerable effect on the raptor population because of the low incidence of mortalities from collisions with power lines compared with the relatively large size of raptor populations in the Project Area.

The presence of new aboveground power lines could increase the potential for raptor electrocutions. All aboveground structures would be designed and equipped with Avian Power Line Interaction Committee (APLIC) (1996) devices intended to prevent and reduce the risk of electrocution to perching raptors. Power lines to facilities would be constructed underground where practical. These lines are expected to account for most of the new lines constructed. Since 1997, the number of collisions and electrocutions reported for eagles, both golden and bald, has steadily increased each year within the PRB. Seacross (2002) reported 83 golden eagles and 2 bald eagles were electrocuted during 2001. Other electrocutions of eagles have likely gone unreported, as have electrocutions of other species of raptors. No data are available on whether these electrocutions occurred on raptor-safe or improperly constructed power lines. Despite the use of raptor-safe construction techniques, electrocutions could occur and may increase over the life of the project as new power lines are built.

Support structures associated with aboveground power lines could be used as perches by raptors. These new perches would provide raptors with new opportunities for hunting and capturing prey, which could increase the efficiencies and success of raptors that hunt from perches. This increase in success could result in an increase in the local population of raptors that hunt from perches and reduce the populations of the species on which these raptors prey. Such a reduction in prey populations would be of concern, particularly when they involve species that already are experiencing reductions, such as sage grouse and mountain plovers. Installing devices to prevent raptors from perching in on structures supporting power lines near sensitive areas, such as grouse leks and mountain plover nesting areas, could eliminate these facilities as perches for raptors.

Disturbance of Habitats

Raptor nesting habitats occur throughout the Project Area. Where active nests are documented during pre-construction surveys, timing stipulations would prohibit construction during the nesting season. Potential nesting habitats would not be similarly protected and could be disturbed or removed during construction of fa-

189

cilities. Ground-nesting raptors would experience a greater loss of nesting habitats relative to cliff- and tree-nesting raptors because cliffs and trees are less likely to be disturbed by the project.

Raptor foraging habitats also occur throughout the Project Area and include all of the habitat types present. Construction of project facilities would disturb or remove a variety of terrestrial habitats that provide foraging areas for raptors. Aquatic habitats that provide foraging opportunities for some species would generally be avoided by the project; however, the effects of water disposal methods may affect aquatic habitats, as discussed below.

Facilities for Handling Produced Water

Approximately 27,009 acres would be disturbed by water handling facilities under this alternative (Table 2–6). Construction of water handling facilities would generally occur in upland areas; however, the specific locations of these facilities are unknown. Because sagebrush shrublands and short- and mixed-grass habitats are the most common and widely distributed habitat types within the Project Area, it was assumed that they would experience most of disturbance associated with construction of water handling facilities. However, avoiding sagebrush shrubland habitats for these facilities where practical would minimize the loss of sagebrush shrubland habitats. Water handling methods would affect prey habitats and, subsequently, prey populations, but would not directly affect raptors. Effects on availability of prey are discussed below.

Harassment and Displacement

Raptors would be temporarily displaced from habitats in areas of human activity. The extent of displacement would depend on the duration and intensity of the activity and on the sensitivity and habituation to disturbance of individuals. Construction may result in displacement from affected habitats during the entire construction phase (a time frame of weeks to months), while production would result in displacement only during well visits (a time frame of hours). When they are displaced, individuals would move to other adjacent habitats but may encounter competition for resources. Resources in avoided areas would be under used, but would be over-used in areas were displaced individuals sought refuge.

Disturbance to nesting raptors can cause nest failure, nest abandonment, and unsuccessful fledging of young. Timing stipulations would not allow new disturbance during the breeding season within species-specific distances of active nests. Raptor surveys would be conducted during the appropriate period to identify these habitats before ground disturbance begins. These measures would minimize harassment of nesting raptors by project activities.

Displacement during the construction phase could alter patterns of habitat use for foraging individuals. Displacement during the production phase would result in only minimal alteration of habitat use by foraging individuals. The relatively widespread occurrence of foraging habitats in the Project Area and the diffuse nature of the expected human activity would preclude substantial changes in raptor foraging behavior. Most human activity would be associated with construction of project facilities but would then diminish during the operation and abandonment phases. During abandonment of project facilities, local activity levels would temporarily increase for a period sufficient to complete habitat restoration.

Noise

Noise is one factor in the displacement of raptors from areas of otherwise suitable habitat and was considered as part of the analysis. Elevated levels of noise associated with increased human activity and facility operations may affect raptors. The effects of project-related noise levels on raptors depend on the patterns of occurrence and intensity of the noise. Responses of individual raptors may vary from tolerance to avoidance of affected habitats. Increased noise in areas adjacent to new compressors would have minimal effects because raptors would avoid these areas or may become accustomed to this type of disturbance.

Availability of Prey

The diverse raptor populations that occur in the Project Area rely on a variety of prey species that make use of different habitats. Project activities would disturb or remove terrestrial habitats that support typical prey species. Prey species, particularly small- and medium-sized mammals, would experience losses as a result of direct mortality, loss of habitat, and habitat fragmentation. Some prey species would respond negatively to these habitat changes, while others would experience positive effects. Overall, the collective distribution and occurrence of these prey species would decrease and may be reduced to the extent that the availability of prey is reduced for foraging raptors, especially in areas of concentrated development.

The potential effects of water handling facilities include localized removal of prey habitats and changes in the population of prey species. In some instances, local habitats may improve through the increased availability of water and, in turn, benefit local prey species and raptors. The effects of increased volumes of water as the result of water disposal methods may disturb, destroy, augment, or create aquatic habitats. Increased volumes of water may disrupt aquatic environments that lead to changes in the occurrence of fish and waterfowl that are sought as prey by some raptor species. Increased volumes of water may result in improvements to habitats that were previously unsuitable for fish or waterfowl.

Habitat Fragmentation

The pattern of fragmentation that would occur from the proposed project, as discussed above, would have minimal effects on raptors because their ability to move through and make use of the remaining habitats that would not be affected. Populations of some prey species, especially smaller mammals, would be affected by fragmentation (Trombulak and Frissel 2000) and may decrease, affecting the availability of prey for raptors.

Population Effects

The effects of the proposed project on raptor populations are difficult to predict because of the many unknown factors associated with each of the potential effects, differing sensitivity of species to each of these effects, and the potential for synergistic relationships among the individual effects. The large scale and widespread nature of the anticipated impacts, particularly in terms of collisions, power line electrocutions, displacement, and availability of prey species, suggest that some declines in raptor populations may occur. The degree of this potential decline is not known, but is not likely to occur to the extent that raptor population viability is compromised in the Project Area or across the range of any specific species as a whole.

Alternative 2A

Under Alternative 2A, the magnitude and type of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 36,263 acres would be disturbed by water handling facilities under this alternative (Table 2–23), an increase of 34 percent over the disturbance from water handling associated with Alternative 1; therefore, a similar increase in effects from water handling is expected.

Alternative 2B

Under Alternative 2B, the magnitude and type of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 32,653 acres would be disturbed by water handling facilities under this alternative (Table 2–25), an increase of 21 percent over the disturbance from water handling associated with Alternative 1; therefore, a similar increase in water handling effects is expected.

Alternative 3

Under Alternative 3, the types of effects to raptors would be similar to those presented for Alternative 1; however, the magnitude of these effects would be substantially smaller. Alternative 3 would result in the disturbance of 35 percent of the amount of habitats (Table 2–32) that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent (Table 2–29). The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller. Approximately 11,683 acres would be disturbed by water handling facilities under this alternative (Table 2–32), a decrease of 57 percent from the disturbance from water handling associated with Alternative 1. The reduction in impacts from project activities, including water handling facilities, would result in reduced impacts to raptors. Despite this reduction, the large scale and widespread nature of the anticipated impacts, particularly in terms of collisions, power line electrocutions, displacement, and prey species availability, suggest that some declines in raptor populations may occur. The degree of this potential decline is not known, although it would be smaller than under the other three alternatives. The decline is not likely to occur to the extent that viability of the raptor population is compromised in the Project Area or across the range of any specific species as a whole.

174

BEST COPY AVAILABLE

Cumulative Effects

Implementation of each of the alternatives would contribute to cumulative effects to raptors in the Project Area. The cumulative effects to raptors that would result from current, proposed, and future activities such as gas and mineral exploration and development, agriculture, and urban development may include increased disturbance to nesting raptors, degradation or destruction of nesting habitats, increased raptor collisions with power lines, increased electrocutions, and increased vehicular collisions with raptors feeding on carrion. As development brings additional power lines to the Project Area, the use of power poles as perches may be a positive effect to raptors.

The total acreage affected by development of CBM would not be disturbed simultaneously because development would occur over the life of the project. Some of the disturbed acreage would be reclaimed or would be in the process of being reclaimed when new disturbances are initiated. Development of CBM is expected to occur at a rate faster than abandonment and reclamation of wells. In the near future, the amount of disturbed habitats is likely to increase, although the anticipated life of CBM wells indicates that reclamation would eventually overtake development of new wells, resulting in a net decrease in disturbed vegetation for the long term. In areas reclaimed after development of CBM, vegetation often differs substantially from undisturbed areas, as discussed in the section on Vegetation. As a result, shifts in composition or distribution of habitat would affect raptor species within the Project Area.

Upland Game

Activities associated with the proposed project would affect upland game species in several ways. The effects to upland game may include: (1) increased direct mortality (including legal hunting, poaching, and collision with power lines and vehicles); (2) the introduction of new perches for raptors and thus a potential change in predation rates; (3) direct loss or degradation of habitats; (4) indirect disturbance resulting from human activity (including harassment, displacement, and noise); (5) habitat fragmentation (particularly through construction of roads); and (6) changes in population levels. Specific concerns for greater sage grouse and plains sharp-tailed grouse were identified during the scoping process. The greater sage grouse is discussed in detail in the section on Threatened, Endangered, or Sensitive Species. Plains sharp-tailed grouse are discussed below. No other species were specifically identified during the scoping process.

Alternative 1

Direct Mortality

Plains sharp-tailed grouse are legally hunted in the Project Area and poaching likely occurs as well. The new roads would increase access to lands in the Project Area. Increased access to public lands would result in more use of these areas by hunters and an increase in hunting pressure (legal and illegal). Private landowners would continue to control access to, and hunting on, split estate and private lands. Nevertheless, some increase in the level of poaching may occur the Project Area is sparsely populated. This increase in hunting pressure would have a minor effect on plains sharp-tailed grouse because public access to the high proportion of private lands is unlikely.

Vehicle Collision

The potential for collisions with vehicles was addressed because grouse tend to flush when closely approached and then fly close to the ground. Few studies have specifically examined effects of collision with vehicles on upland game. The literature on avian mortality caused by collision with vehicles is reviewed by Erickson et al. (2001). Hoffman (2001) did not mention vehicle collision as a specific impact on sharp-tailed grouse in northwestern Colorado, an area that has a similar level of development of roads. The new roads that would be constructed under this alternative increase the potential for vehicle collisions with sharp-tailed grouse. Although the number of collisions between vehicles and sharp-tailed grouse may increase, the effect on the grouse's overall population would be minimal because development would be dispersed and surveys for leks would define areas where sharp-tailed grouse concentrate.

Power Line Collision

Relatively few comprehensive studies have been conducted, and nationwide annual estimates of avian mortality caused by collision with power lines are highly variable. The literature on avian mortality caused by collision with power lines is reviewed by Erickson et al. (2001). Upland game birds are unlikely victims of collisions with power lines because they fly close to the ground. Thus, the effects of collisions with power lines on populations of sharp-tailed grouse would be minimal.

Predation by Raptors

Construction of power lines could increase the number of perching opportunities for raptors. The availability of these perches may result in increased raptor hunting pressures on sharp-tailed grouse, particularly if perches are available near leks during the breeding season. Sharp-tailed grouse do not appear as sensitive as are sage grouse to placement of power lines near leks (Hoffman 2001). Raptor-proofing aboveground power lines within one-half mile of lek sites would reduce the potential for increased raptor predation on sharp-tailed grouse. With raptor-proofing of power lines, increases in predation by raptors would be experienced primarily by foraging birds and are expected to have only minor effects on populations of sharp-tailed grouse.

Loss or Degradation of Habitats

Implementation of this alternative would disturb sharp-tailed grouse habitats. Table 4–52 shows the predicted proportion of known lek sites where project-related facilities would be placed within 0.25 mile. Data on lek locations would be reviewed before surface disturbance begins to avoid direct disturbance to leks. Predisturbance surveys would be conducted in suitable grouse habitats to locate leks that may be disturbed. No surface occupancy would be allowed within ¼ mile of a lek to avoid direct disturbance. This stipulation is attached to oil and gas leases and is non discretionary. Therefore, it applies to all federal oil and gas leases, regardless of surface ownership. Habitat disturbance to brood-rearing habitats and feeding and resting areas would occur. Disturbances to wooded draws and riparian areas would be avoided, with the exception of linear facilities, such as roads, pipelines, and power lines. Direct loss and disturbance of habitats is expected to have minor effects on sharp-tailed grouse because of mitigation measures designed to reduce impacts to important habitats and because they can adapt to altered habitats as long as important components such as shrubby areas and wooded draws are protected (Braun et al. in press).

Table 4–52 Effects to Sharp-tailed Grouse Protective Buffers by Sub-watershed – Alternatives 1, 2A, and 2B

Sub-watershed	Portion of leks with development proposed in the buffer (percent)			
	Project		Cumulative	
	¼-mile buffer	½-mile buffer	¼-mile buffer	½-mile buffer
Little Bighorn River	0.0	0.0	0.0	0.0
Upper Tongue River	18.5	29.6	22.2	29.6
Middle Fork Powder River	0.0	0.0	0.0	0.0
North Fork Powder River	0.0	0.0	0.0	0.0
Upper Powder River	0.0	0.0	0.0	0.0
South Fork Powder River	0.0	0.0	0.0	0.0
Salt Creek	0.0	0.0	0.0	0.0
Crazy Woman Creek	0.0	0.0	0.0	0.0
Clear Creek	14.3	57.1	28.6	71.4
Middle Powder River	0.0	0.0	0.0	0.0
Little Powder River	0.0	0.0	0.0	0.0
Little Missouri River	0.0	0.0	0.0	0.0
Antelope Creek	0.0	0.0	0.0	0.0
Dry Fork Cheyenne River	0.0	0.0	0.0	0.0
Upper Cheyenne River	0.0	0.0	0.0	0.0
Lightning Creek	0.0	0.0	0.0	0.0
Upper Belle Fourche River	0.0	0.0	0.0	0.0
Middle North Platte River	0.0	0.0	0.0	0.0
Total	15.0	30.0	20.0	32.5

Water Handling

Under this alternative, water-handling methods may have positive and negative effects to the sharp-tailed grouse. Produced water from surface discharge may result in expansion of existing wetlands and riparian areas and create new areas of these habitats. Water impoundments and increased water flows would also provide additional sources of drinking water. The construction of water handling facilities would result in the loss of habitats used by this species. A total of 27,009 acres would be disturbed by construction of the various water handling facilities. A summary of losses by habitat type, including contributions from water handling methods, is presented in the section on Vegetation of this chapter.

Harassment, Displacement, and Noise

Human disturbance, including noise from project facilities, may result in adverse effects to sharp-tailed grouse. These grouse are most sensitive to human activity and noise when on their leks, although they do not appear to be as sensitive as sage grouse (Hoffman 2001). Human activities may disturb individual nesting

195

grouse, but effects to groups of grouse during the breeding period would have the greatest potential to affect local populations. Table 4–52 shows the predicted proportion of known lek sites where project-related facilities would be located within 0.5 mile and, therefore, that could be subject to displacement. The potential for adverse effects on federal or split estate lands from harassment, displacement, and noise would be minmal because timing limitations (stipulations) would prevent new surface disturbance within 0.5 mile of sites during the breeding period and the mitigation measure on noise would limit the level of noise allowed at leks.

Habitat Fragmentation

Sharp-tailed grouse may move more than 18 miles between seasonal ranges (Hoffman 2001). During these migrations, they can cross highways, roads, agricultural fields, and other areas of non-native habitats. The level of fragmentation that would occur would not substantially fragment habitats used by sharp-tailed grouse and is not expected to affect patterns of habitat use or seasonal movements on a landscape scale.

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 36,263 acres would be disturbed by water handling facilities under this alternative (Table 2–23), an increase of 34 percent over the water handling disturbance associated with Alternative 1; therefore, a similar increase in effects from water handling is expected.

Alternative 2B

Under Alternative 2B, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 32,653 acres would be disturbed by water handling facilities under this alternative (Table 2–25), an increase of 21 percent over the disturbance from water handling associated with Alternative 1; therefore, a similar increase in water handling effects is expected.

Alternative 3

Under Alternative 3, the types of effects to upland game birds would be similar to those presented for Alternative 1. The magnitude of these effects would be substantially smaller, however. Alternative 3 would result in the disturbance of 35 percent of the amount of habitats that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent. Table 4–53 shows the predicted proportion of known sharp-tailed grouse lek sites where project-related facilities would be located within 0.25 and 0.5 mile. The effects from water handling would be essentially the same as were

196

discussed for Alternative 1; however, the magnitude of these effects would be smaller. Approximately 11,683 acres would be disturbed by water handling facilities under this alternative, a decrease of 57 percent from the disturbance from water handling associated with Alternative 1. The reduction in impacts from project activities, including water handling facilities, would reduce impacts to upland game birds.

Cumulative Effects

Implementation of each of the alternatives would contribute to cumulative effects to upland game birds that occur within the Project Area. The cumulative effects to upland game that would result from current, proposed and future activities such as gas and mineral exploration and development, agriculture, and urban development may include increased mortality, especially from collisions with vehicles and power lines; displacement and harassment; and physical degradation or destruction of breeding grounds (leks) and reproductive areas (nesting and brood-rearing areas). Table 4–52 and Table 4–53 show the predicted cumulative proportion of known sharp-tailed grouse lek sites where project-related facilities would be located within 0.25 and 0.5 mile for each of the alternatives.

Table 4–53 Proposed and Cumulative Impacts to Sharp-tailed Grouse Protective Buffers by Sub-watershed — Alternative 3

Sub-watershed	Portion of leks with development proposed in the buffer (percent)			
	Project		Cumulative	
	0.25-mile buffer	0.5-mile buffer	0.25-mile buffer	0.5-mile buffer
Little Bighorn River	0.0	0.0	0.0	0.0
Upper Tongue River	14.8	25.9	18.5	29.6
Middle Fork Powder River	0.0	0.0	0.0	0.0
North Fork Powder River	0.0	0.0	0.0	0.0
Upper Powder River	0.0	0.0	0.0	0.0
South Fork Powder River	0.0	0.0	0.0	0.0
Salt Creek	0.0	0.0	0.0	0.0
Crazy Woman Creek	0.0	0.0	0.0	0.0
Clear Creek	0.0	57.1	14.3	71.4
Middle Powder River	0.0	0.0	0.0	0.0
Little Powder River	0.0	0.0	0.0	0.0
Little Missouri River	0.0	0.0	0.0	0.0
Antelope Creek	0.0	0.0	0.0	0.0
Dry Fork Cheyenne River	0.0	0.0	0.0	0.0
Upper Cheyenne River	0.0	0.0	0.0	0.0
Lightning Creek	0.0	0.0	0.0	0.0
Upper Belle Fourche River	0.0	0.0	0.0	0.0
Middle North Platte River	0.0	0.0	0.0	0.0
Total	10.0	27.5	15.0	32.5

The total acreage affected by development of CBM would not be disturbed simultaneously because development would occur over the life of the project. Some of the disturbed acreage would be reclaimed or would be in the process of being reclaimed when new disturbances are initiated. Development of CBM is expected to occur at a rate faster than abandonment and reclamation of wells. In the near future, the amount of disturbed habitats is likely to increase, although the anticipated life of CBM wells indicates that reclamation would eventually overtake development of new wells, resulting in a net decrease in disturbed vegetation for the long term. In areas reclaimed after development of CBM, vegetation often differs substantially from undisturbed areas, as discussed in the section on Vegetation. As a result, shifts in habitat composition or distribution would affect upland game species within the Project Area.

Waterfowl

Alternative 1

Surface disturbance associated with the construction, operation, and abandonment of facilities, including roads, has little potential to cause direct mortality to waterfowl. Most birds would avoid construction equipment and most construction would not occur within or near wetland habitats. However, nests placed in locations subject to disturbance (such as tall grass near wetlands) could be lost. This effect would be relatively minor because of the low potential for direct mortality, the short breeding season for waterfowl, and the small percentage of the Project Area that would be directly affected during the breeding season.

Exposure to Production Water

Concentrations of salts and metals, particularly barium and selenium, may increase in the containment reservoirs receiving CBM produced water discharges, as water evaporates over time. Direct effects (toxicity) to waterfowl could occur, depending on the quality of the produced water. CBM produced waters discharged to off-channel containment impoundments would require an NPDES permit issued by WDEQ, which would establish effluent limitations that would be protective of use by wildlife and livestock. Concentrations of selenium within the impoundments would be monitored as a requirement of the NPDES permit, primarily because of the large volume of water that could be potentially discharged, and the bioaccumulative nature of selenium. Typically, the concentration of selenium in the produced water is fairly low and is normally less than Wyoming water quality standards. However, water quality could reach levels of concern for selenium and other constituents when inflow to the impoundments ceases, and NPDES permit monitoring requirements no longer apply.

Selenium can be absorbed or ingested by organisms, can bind to particulate matter, or can remain free in solution. Most selenium accumulates in the top layer of sediment and detritus. Selenium can then be cycled back into the biota and remain elevated for years after input of selenium has stopped (Lemly and Smith 1987). Generally, flowing waters accumulate less selenium than do standing waters, which have low rates of flushing. Recovery is much slower in shallow impoundments and wetlands than in fast-flowing rivers and streams (Lemly and Smith 1987). Selenium levels in the water column that exceed 10 µg/L are considered to pose a potential risk to many species of waterfowl because of the element's known toxicological effects and high potential for bioaccumulation in food chains (Lemly and Smith 1987). Results for recent sampling of produced water within the Project Area show that levels of selenium are less than 2 μg/L. However, bioaccumulation of selenium may result as more is introduced into the ecosystem. Selenium could potentially reach toxic levels for fish over the life of the project. Fish and macroinvertebrate species that live in ponds and reservoirs that receive CBM produced water may experience effects from bioaccumulation of selenium, which may affect waterfowl through ingestion of these species. Levels of selenium in streams and rivers throughout the Project Area are not expected to reach harmful levels for waterfowl due to NPDES permit requirements for CBM produced water discharges that are protective of aquatic life.

The saline quality of the produced water would likely precipitate dissolved metals in the water column, such that sediments beneath CBM produced water containment reservoirs would potentially receive increasing concentrations of organic and inorganic forms of dissolved metals over time. It is possible that sediments would reach a toxic level for diving ducks that ingest sediments while they feed on benthic organisms. Changes in algal and microbial species richness that could cause indirect effects on waterfowl may or may not occur in response to increasing concentrations of metals (Adamus 1996). Some aquatic organisms are able to develop a tolerance to an increased concentration of metals in the surrounding aquatic environment. Tolerance may be described as "the ability of individuals to cope with the stress associated with exposure to contaminant concentrations that are inhibitory to non-tolerant individuals" (Mulvey and Diamond 1991). Explanations to account for increased tolerance to contaminants include physiological acclimation and genetic adaptation (Clements 1999). The physiological and genetic mechanisms responsible for tolerance may come at specific costs. Several studies have documented a tradeoff within individuals between the benefits of tolerance and the associated energetic costs, with consequences for populations and communities (Hickey and McNeilly 1975, Wilson 1988, Courtney and Clements 2000). Courtney and Clements (2000) reported that chronic metal pollution produced aquatic invertebrate communities that were tolerant to metals but were more sensitive to acidic pH. Clements (1999) reported that both population-level responses and species replacement accounted for greater tolerance to high concentrations of metals by aquatic invertebrates in stream contaminated by metals.

Limits on salinity and optimum ranges for microbial communities, algae, and aquatic invertebrates are known for many species. It is likely that the containment reservoirs receiving CBM produced water would be colonized by species of these taxa that are tolerant of the saline water quality compared with surrounding water bodies. The species richness of microbial communities and aquatic invertebrates, as well as algal productivity and biomass, would likely be less in the CBM produced water containment reservoirs than in less-saline water bodies (Adamus 1996). As the salinity increases over time and as water evaporates from the containment reservoirs, these bioindicators would decrease. Similarly, the species richness and abundance of waterfowl is expected to be lower than in surrounding, unaffected water bodies.

199

Collision with Vehicles

Annual avian mortality from collisions with vehicles in the United States is estimated to be equal to 60 to 80 million birds, most of which are songbirds. The literature on avian mortality caused by collision with vehicles is reviewed by Erickson et al. (2001). It was estimated that 13,500 ducks are killed each year from vehicle collisions in the prairie pothole regions of North and South Dakota (some of the most productive waterfowl habitat in the U.S.). An average number of 0.04 duck fatalities per mile of road has been used by several authors to estimate total waterfowl mortality from vehicle collisions in the prairie pothole region (Erickson et al. 2001). Most of these studies have been conducted along paved, high-speed roads, rather than low-speed dirt roads. The rate of mortality with mostly unpaved project roads in the drier PRB would be much lower than reported for the prairie pothole ragion. Thus, the effects of collisions of waterfowl with vehicles on the local populations of waterfowl would not be anywhere near as extensive as the estimate for the prairie pothole region.

Collisions with Power Lines

Few comprehensive studies have been conducted on collisions of birds with power lines. However, where nationwide annual estimates of avian mortality caused by such collisions have been made, they range widely, from more than 10,000 to more than 174,000,000 birds per year. Waterfowl are most susceptible to colliding with power lines that span or occur near streams, water bodies, and wetlands. Considering the amount of open water and wetlands in the Project Area, the potential for waterfowl colliding with power lines is limited and minimizing the construction of aboveground power lines near streams, water bodies, and wetlands would reduce the potential for these collisions.

Increased Raptor Predation

Construction of power lines would increase the number of perching opportunities for raptors. The bald eagle is one of the primary species of raptor in the Project Area that takes a large percentage of waterfowl as prey. Eagles typically hunt on the wing and hunt from perches. Therefore, an increase in the number of raptor perches may facilitate hunting by bald eagles. However, any effects on waterfowl from this facilitation probably would be negligible because amount of suitable habitats present in the PRB is limited and the distribution of these habitats relative to routes for power lines would minimize the potential for placement of power lines where they would benefit bald eagles. Furthermore, raptor proofing the power lines would eliminate the use of electrical structures as perches by raptors.

Loss or Degradation of Habitats

The extent of loss of various habitat types in the Project Area is discussed above. Wetlands and riparian areas are the habitat types of highest importance to the waterfowl in the Project Area. The amounts of these habitat types that would be lost are relatively small compared with the areal extent of these habitats that would not be affected. Thus, direct loss of habitats would have minimal effect on waterfowl.

Water Handling

Habitat disturbance as the result of applied water handling methods would result in a variety of changes, including potential negative and positive effects to habitats for waterfowl. Water from impoundment outflows and surface discharge may create new and improve existing feeding, nesting, and resting habitats by supplementing current seasonal water regimes. New feeding, nesting, and resting habitats may be provided to local waterfowl, assuming rooted aquatic plants and wetland vegetation are allowed to grow at surface containment facilities. Waterfowl populations in the Project Area may increase in response to new or expanded habitats caused by surface water discharge. This potential increase in populations also may lead to an increased occurrence of power line collisions and raptor predation.

Production water from impoundment outflows and surface discharge may also negatively affect existing waterfowl habitats. Inputs to existing aquatic habitats from production water may alter favorable conditions to the detriment of plants and aquatic life. These potential effects depend on existing conditions, the quantity and timing of the release of production waters, and the distance between release points and existing waterfowl habitats. Although these circumstances may occur in the Project Area, they are not expected to notably affect the waterfowl population in the Project Area.

Harassment and Displacement

Waterfowl could be displaced from habitats in areas of human activity. The extent of displacement would depend on the spatial and temporal scale of the activity and the response of each species and individual to each type of disturbance. Individuals may be completely displaced from their territories for extended periods in areas where construction and drilling occur during the breeding season. These individuals may be able to use habitats adjoining the disturbance; however, these habitats may already be occupied. Displacement probably would not have substantial effects on waterfowl populations because development at any single location would be limited in time, would occur primarily in uplands, and few wetlands would be disturbed directly.

Limited displacement also could occur during the operational phase. Disturbance during the operational phase would be short and could occur regularly in some areas. During this phase, individuals would be displaced temporarily (a few hours at most) rather than for any extended period.

Noise

Noise is one component of disturbance that could cause displacement, depending on the proximity of the source of noise to waterfowl and their habitats. Regular noise from stationary sources, such as compressors, can disrupt bird behavior, such as territorial defense, mate attraction, and warning calls, within a limited distance around the source (NPC 2002, Stone 2002). Individual birds may avoid nesting in areas of regular noise, which would effectively reduce the amount of breeding habitats available. Mitigation measures designed to minimize effects from noise that are associated with compressors would limit the potential extent of the noise to the immediate vicinity of these facilities. Overall, the effect of

201

noise on waterfowl across the Project Area would be minor because sources of noise would be limited and the areal extent of habitats for waterfowl is limited.

Habitat Fragmentation

Habitats used by waterfowl, such as wetlands and riparian areas, would be only minimally fragmented by the project. Linear facilities may cross these habitats, but this disturbance is expected to have minimal effects on individual waterfowl or populations specifically as a result of fragmentation.

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 36,263 acres would be disturbed by water handling facilities under this alternative, an increase of 34 percent over the disturbance from water handling associated with Alternative 1. Populations of waterfowl would be subject to the same effects as were discussed under Alternative 1; therefore, a similar increase in effects from water handling is expected.

Alternative 2B

Under Alternative 2B, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 32,653 acres would be disturbed by water handling facilities under this alternative, an increase of 21 percent over the disturbance from water handling associated with Alternative 1. Populations of waterfowl would be subject to the same effects as were discussed under Alternative 1; therefore, a similar increase in water handling effects is expected.

Alternative 3

Under Alternative 3, the types of effects to waterfowl would be similar to those presented for Alternative 1. The magnitude of these effects would be substantially smaller, however. Alternative 3 would result in the disturbance of a substantially smaller amount of habitats than would be affected under Alternatives 1, 2A, and 2B because the total number of new wells would be reduced to 40 percent. The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller. Approximately 11,683 acres would be disturbed by water handling facilities under this alternative, a decrease of 57 percent from the disturbance from associated with Alternative 1. The reduction in impacts from project activities, including water handling facilities, would reduce impacts to waterfowl.

Cumulative Effects

Implementation of each of the alternatives would contribute to cumulative effects to waterfowl that inhabit the Project Area. Potential negative cumulative effects

202

may result after each of the proposed alternatives is implemented. Negative effects would include degradation of existing nesting, feeding, and resting habitats from potential increases or fluctuations in surface water levels. Salts and metals may also bioaccumulate within containment reservoirs, streams, and rivers over time, and levels may exceed the safe limit for waterfowl. Positive effects would include the potential creation of suitable nesting, resting, or feeding habitats associated with the various methods of water handling.

The effects to waterfowl described for each of the proposed alternatives would occur in addition to impacts that have already occurred, and that would occur, as a result of other activities in the Project Area. Similar types of direct and indirect effects have already occurred, including direct mortality, habitat loss, indirect effects, and population-level effects. Minimal downward trends in populations of waterfowl are predicted.

Migratory Birds

Alternative 1

Surface disturbance associated with construction, operation, and abandonment of facilities, including roads, has the potential to result in direct mortality of migratory birds. Most birds would be able to avoid construction equipment; however, nests in locations subject to disturbance would be lost, as would any eggs or nestlings. This effect would be relatively minor because of the low potential for direct mortality, the short breeding season for migratory birds, and the small percentage of the Project Area that would be directly affected during the breeding season.

Vehicle Collision

Annual avian mortality from collisions with vehicles in the United States is estimated to be equal to 60 to 80 million birds, most of which are passerines. The literature on avian mortality caused by collision with vehicles is reviewed by Erickson et al. (2001). The number of collisions between vehicles and migratory birds probably would increase with the construction of the new roads. However, the number of collisions in the literature varies so widely (from two to three to well more than 100 per mile of highway) that any quantitative projection for the Project Area would be speculative. Although the number of collisions would probably increase, the effects on populations of migratory birds is unlikely to be substantial because the roads that would be constructed would be low-speed two track and gravel roads.

Power Line Collision

Relatively few comprehensive studies have been conducted and nationwide annual estimates of avian mortality caused by collisions with power lines vary from more than 10,000 to 174,000,000. The literature on avian mortality due to collision with power lines is reviewed by Erickson et al. (2001). Waterfowl appear most susceptible to collision with power lines near wetlands, whereas raptors and migratory birds are most susceptible in upland areas. It is likely that mortalities to migratory birds in the Project Area would increase as a result of the proposed project.

Loss or Degradation of Habitats

The extent of loss of various habitat types in the Project Area is discussed above. Shortgrass prairie, sagebrush shrublands, and wetlands and riparian areas are the habitat types of highest importance to the species of migratory birds of management concern in Wyoming. Species that depend on these habitats have shown large declines in population size as a result of habitat loss (Saab and Rich 1997). Each of these habitats supports several species of birds that are of management concern (Cerovski et al. 2001). The amount of each of these habitats that would be disturbed is relatively small compared with the areal extent of these habitats that would not be affected. Operation of water handling facilities may increase the availability of riparian habitats, benefiting some species, including migratory birds. Direct loss of habitat would have minimal effect on migratory birds.

Harassment and Displacement

Migratory birds would be displaced from habitats in areas of human activity. The extent of displacement would depend on the spatial and temporal scale of the activity and on the response of each species to each type of disturbance. In areas of construction and well drilling, individuals may be completely displaced from their territories for extended periods. These individuals may be able to use adjacent habitats away from the disturbance; however, in many cases, these habitats would already be occupied and competition for limited resources would occur.

Displacement would continue during the operational phase, although the nature of disturbance would change. Rather than areas of intense, continuous activity, disturbance during the operational phase would be short and would occur on a regular basis across a broad area. During this phase, individuals may be displaced for a short period (a few hours at most), but would not move into new areas or compete substantially with birds in other areas.

Noise

Noise associated with various project activities is one component of disturbance that would result in displacement. Regular noise from stationary sources, such as compressors can disrupt bird behavior, such as territorial defense, mate attraction, and warning calls, within a limited distance around the source (NPC 2002, Stone 2002). Individual birds may avoid nesting in areas of regular noise, effectively reducing the amount of available breeding habitat. Mitigation measures designed to minimize noise effects associated with compressors to specific areas, such as around grouse leks, would limit the extent of this effect to the immediate vicinity of these facilities. The overall effect of noise generated by the project on populations of migratory birds would be minor.

Habitat Fragmentation

Knick and Rotenberry (1995) found that percentage of cover and size of sagebrush patches influenced the abundance of breeding sage sparrows in fragmented sagebrush shrublands. This study was conducted in an area where 50 percent of sagebrush shrublands had been lost. Ingelfinger (2001) found that densities of breeding sagebrush-obligate passerines in an area with a lower proportion of sagebrush loss were reduced by 50 percent within 100 meters of roads, even along lightly used oil and gas development roads. Other birds, specifically horned larks, increased in density near roads (Ingelfinger 2001). Habitat fragmentation in shrub-steppe (sagebrush and other shrubland) habitats affects site selection, reproductive rates, and predation rates (Knick and Rotenberry 1995), all of which may explain the lower abundance of sagebrush-obligate songbirds in fragmented shrub-steppe habitats. The creation of edges in other habitats can also lead to increased predation and nest parasitism (Paton 1994). The results of these studies suggest that densities of some migratory birds may decline in parts of the Project Area that are disturbed by project activities whereas the densities of other species may increase.

Population Effects

The combination of direct habitat loss, displacement, and habitat fragmentation probably would result in some decline in the populations of migratory birds that are sensitive to these types of disturbance, such as sagebrush-obligate songbirds. Populations of other species that are adaptable to disturbance (such as horned larks) may increase. Table 4–54 shows qualitative predictions for population trends for the species of migratory birds of management concern in Wyoming that were discussed in Table 3–60. The predictions are based on the results from past breeding bird surveys combined with the habitat requirements of each species, as discussed in Cerovski et al. (2001).

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 36,263 acres would be disturbed by water handling facilities under this alternative, an increase of 34 percent over the disturbance from water handling associated with Alternative 1. Populations of migratory birds would be subject to the same effects as were discussed under Alternative 1; therefore, a similar increase in effects from water handling is expected.

Alternative 2B

Under Alternative 2B, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 32,653 acres would be disturbed by water handling facilities under this alternative, an increase of 21 percent over the disturbance from water handling associated with Alternative 1. Populations of migratory birds would be subject to the same effects as were discussed under Alternative 1; therefore, a similar increase in effects from water handling is expected.

Table 4–54 Predicted Population Trend for Migratory Bird Species of Management Concern in Wyoming

Species	Predicted Trend	Comments
Level I species		
McCown's Longspur	Increase	Uses early successional landscape with low shrub density and substantial bare ground.
Wilson's Phalarope	Stable	Habitats would generally be avoided by activities. Discharge of surface water may increase habitat temporarily, but may be low quality, habitat would not persist after abandonment.
Level II species		
Cassin's Kingbird	Stable	Peripheral breeder in Project Area.
Lark Bunting	Stable	May decrease locally in response to high levels of disturbance. Requires 10 to 30 percent dense grass or shrub cover for nesting.
Dickcissel	Decrease	Requires dense cover and large patches of undisturbed habitat.
Chestnut-collared Longspur	Decrease	Requires denser vegetation than McCown's longspur.
Willow Flycatcher	Stable	Riparian obligate – habitat may increase through surface discharge of produced water, but may be low quality, habitat would not persist after abandonment.
Marsh Wren	Stable	Habitats would generally be avoided by activities. Discharge of surface water may increase habitat temporarily, but may be low quality, habitat would not persist after abandonment.
Western Bluebird	Stable	Uncommon in Project Area, minimal effects to preferred habitats.
Grasshopper Sparrow	Decrease	Requires high level of structure, continuous tall cover, and large undisturbed patches.
Bobolink	Decrease	Requires high level of structure, tall cover, and large undisturbed patches.
Black-billed Cuckoo	Stable	Habitats would generally be avoided by activities. Discharge of surface water may increase habitat temporarily, but development of necessary habitat components may not occur.
Vesper Sparrow	Decrease	Requires both shrub and grass cover, a ground nester susceptible to nest destruction and predation.
Lark Sparrow	Decrease	Requires shrub cover, a ground nester susceptible to nest destruction and predation.

Alternative 3

Under Alternative 3, the types of effects to migratory birds would be similar to those presented for Alternative 1. The magnitude of these effects would be substantially smaller, however. Alternative 3 would result in the disturbance of 40 percent of the amount of habitats that would be affected under Alternatives 1, 2A, and 2B because the total number of new wells would be reduced to 40 percent. Approximately 11,683 acres would be disturbed by water handling facilities under this alternative, a decrease of 57 percent from the disturbance from water handling associated with Alternative 1. The reduction in impacts from project activities, including water handling facilities, would result in reduced impacts to migratory birds. Each of the effects discussed for Alternative 1 would occur; however, fewer individual birds would be affected because fewer acres overall would be disturbed by this alternative. The overall effect on populations of birds in the Project Area would also be reduced. The qualitative predictions of trend shown in Table 4–54 for each of the species of management concern in Wyoming are applicable, but any increase or decrease would be reduced proportionally to the reduction in impacts between Alternative 3 and the other alternatives.

Cumulative Effects

The effects to migratory birds described for each of the proposed alternatives would occur in addition to impacts that have already occurred and that would occur as a result of other activities in the Project Area. Similar types of direct and indirect effects have already occurred, including direct mortality, habitat loss, displacement, habitat fragmentation, and population-level effects. Evaluating the cumulative impacts of past, on-going, and reasonably foreseeable activities is difficult because of the general lack of data on migratory birds in the Project Area and the range of effects that would occur in varying degrees to various species. The trends discussed in Table 4–54 would be applicable not only to proposed effects, but also to cumulative effects because they take into account existing data on trends.

Aquatic Species

This section describes the potential direct and indirect effects of each of the proposed alternatives on aquatic species in the Project Area. These effects include: (1) changes in timing and quantity of stream flows; (2) changes in sedimentation; (3) changes in concentrations of salts in streams; (4) changes in concentrations of metals (such as barium, selenium); (5) changes in temperatures; (6) accidental spills of fuels or drilling fluids; (7) changes in species diversity; and (8) transboundary effects on water quality.

This analysis assumed that wells that discharge produced water on the surface and wells that discharge water to infiltration ponds may have potential effects on aquatic species. Water produced from wells and managed using other -methods of water handling (containment, LAD, and injection) would not have effects on surface waters because none of the discharged water under these methods would reach drainages in the sub-watersheds; therefore, these three water-handling methods are not analyzed further. The amount of water that would enter drainages below infiltration ponds as a result of the rising water tables in shallow aquifers is unknown; however, if some of this water resurfaces into stream channels, it would contribute to the effects discussed below.

Discharges of CBM produced water to surface drainages would not result in violations of the Clean Water Act if the project adheres to the requirements in WDEQ-issued NPDES permits. NPDES permits specify water quality standards intended to protect designated uses, such as agriculture, livestock watering, and aquatic health. Therefore, under the WDEQ permitting process, the quality of receiving waters in the Powder River Basin would not be degraded to levels above aquatic life standards in tributaries and main stems. Additionally, the BLM APD permitting process requires that Water Management Plans be submitted before CBM water can be discharged (Appendix I).

Alternative 1

The analysis of effects is organized on a sub-watershed basis. The prediction of impacts on the level of individual aquatic species is impractical because of the scale of the Project Area and the lack of scientific data on aquatic resources in the Project Area. Refer to Table 3-57 and Table 3-58 for fish species and their preferred habitats that may occur within a sub-watershed. Under Alternative 1, 62 percent of the proposed wells would discharge produced water on the surface and 23 percent would discharge produced water to infiltration reservoirs.

Timing and Quantity of Stream Flows

Modification of flow is one of the most widespread human disturbances of stream environments (Bain et al. 1988).A change in streamflow translates into a change in the water depth and velocity for any specific location in a stream. Consequently, changes in streamflow can be regarded as modifications to the physical composition of the aquatic habitat (Bain et al. 1988). Fishes that inhabit streams within the Project Area are frequently exposed to disturbances from floods and droughts and must persist in environments that are characterized by fluctuating flows. Changes in the pattern of these fluctuating flows can be viewed as a disturbance in the stability of stream habitat.

Potential negative effects to fish and invertebrates caused by changes in flow are listed and described in Table 4–55 and Table 4–56. These effects include physical, behavioral, habitat, and food changes that may occur if streamflows are increased or decreased substantially, especially during spawning. Increased streamflows could make it difficult for certain species to migrate upstream to spawning and rearing areas, especially in reaches where manmade barriers exist (such as dams and water diversions). Increased flows in rearing areas may also make survival more difficult for young fish. Bain et al. (1988) and Fausch and Bramblett (1991) reported that the shallow and slow-water fishes were adversely affected by an artificially high variability in flow. Decreases in flow force fish that are restricted to shallow areas to relocate to maintain the specific habitat conditions. Rapid increases in flow may expose shallow-water fish to increased predation because shallow shoreline areas become accessible to larger piscivores as depth increases (Bain et al. 1988). In contrast, generalist species that use mid-stream type habitats responded positively to increased variability in flows (Bain et al. 1988). Very few scientific studies have addressed the changes to macroinvertebrate populations caused by changes in stream flow (Gore 1987). It has been assumed that responses of macroinvertebrates to stream flow changes would closely match those of fish; however, macroinvertebrates lack the rapid reinvasion capabilities of fish when they live in an environment of fluctuating discharges (Gore 1987). More research is needed to support the general application of studies of macroinvertebrate response to instream flows for regulated flow management (Gore 1987).

Stream flows are expected to increase to varying degrees in all 10 sub-watersheds that would receive CBM produced water under Alternative 1 (Table 4–1). Increasing stream flows could have both positive and negative effects on aquatic species. The main positive effect would be to provide habitat to fish and macroinvertebrates in areas that are normally dry. This new habitat could provide opportunities for population growth. Increased flows may also benefit fisheries

208

where containment or flow-through ponds are developed for fisheries. These ponds could serve as sport fisheries or be used for breeding native species of concern with proper water quality.

Table 4–55 Effects of Discharge Variations on Aquatic Biota. Potential Detrimental Effects of Pulse Releases on Aquatic Animals

Effect	Description of Effect
Flushing	Flushing of animals that are not adapted to high current velocities can eliminate eggs and fry. In channelized sections with a poor channel structure, this phenomenon may be increased.
Drift	Limitation of benthic invertebrates by catastrophic drift.
Habitat	Changes in morphology of the stream channel, as well as bank or sediment erosion, alter the composition of the bed sediments. This alteration, in turn, changes the amount and composition of aquatic fauna. High loads of suspended matter may damage fish through gill clogging or cause animals leave the affected area.
Food	Food depletion may limit the number of organisms. Diminution of benthic invertebrates may occur through erosion of periphyton or macrophytes. Diminution of the fish population would then follow because of the reduced food supply.

Source: Moog 1993

Table 4–56 Effects of Discharge Variations on Aquatic Biota. Potential Detrimental Effects of Sudden Flow Reduction on Aquatic Animals

Effect	Description of Effect
Physiological and Behavioral Limitations	Physiological limitations of species with a high oxygen demand under conditions of low flow may be multiplied by heating if the channel is shallow enough or by a lack of riparian vegetation. Behavioral limitations and interferences with feeding mechanisms induced by flow (such as net-spinning Trichopetera). Faunal depletion because of catastrophic drift caused by reactions to drought.
Physical Limitations	Stranding and possible death of organisms by dessication or asphyxiation during dewatering of areas of the channel substrate.
Habitat Limitations	Reductions of living space during periods of low flow affect the population size, and may be aggravated by formation of channel icings if the water is shallow.
Silt	Deposition of silt by receding water alters the substrate composition and heterogeneity. This alteration, in turn, causes a change in the number and composition of benthic invertebrates, fish eggs, and fry.
Food	Food depletion by desiccation of primary producers diminishes the population size of certain functional feeding groups of benthic invertebrates. Food depletion of benthic invertebrates in turn diminishes the size of the fish population.

Source: Moog 1993

Groundwater depletions may alter current instream flows in isolated streams throughout the Project Area. These areas would be in shallow alluvium where coal seams are near the surface and could experience reductions in stream flows.

209

Instream flows in the overall Project Area would not be altered by groundwater depletion because the affected aquifer is usually very deep.

Aquatic species may be affected, as discussed above, by the amount of CBM produced water discharged to the surface under Alternative 1, especially during periods of low flow and spawning. Based on the preferred habitats of the fish found within the Project Area (Table 3–57), it is likely that an increase in streamflow would favor species such as the longnose dace, shovelnose sturgeon, and sturgeon chub. Other species that favor slower-moving streams, such as the black bullhead, common carp, fathead minnow, golden shiner, green sunfish, largemouth bass, plains minnow, quillback, rock bass, white sucker, and yellow perch, would be negatively affected by an increase in streamflow.

Sedimentation

Excessive sediments deposited on stream and lake bottoms can choke spawning gravels, impair sources of food for fish (macroinvertebrates), fill in rearing pools, and reduce complexity of the habitat in stream channels. Large quantities of suspended sediment can also make it more difficult for fish to find prey and can cause direct physical harm, such as clogged gills. In some cases, anthropogenic disturbances that result in hydrologic modifications can cause sediment deficits that create stream channel scour and cause loss of habitat structure (EPA 1999).

Erosion rates in stream channels increase along with instream flows, which may augment sedimentation in streams. Increased sedimentation can affect aquatic resources by filling interstitial (intergravel) spaces and pool habitats. This increase in sedimentation can reduce the availability of suitable spawning and rearing habitats. Aquatic macroinvertebrates are also highly dependent on interstitial spaces for different life stages, and sedimentation can cause large decreases in population and change species composition. Benthic invertebrates are excellent candidates for monitoring sediment conditions in streams because substrate is believed to be the most important factor in regulating invertebrate distribution and abundance at the local or reach scale (Zweig and Rabeni 2001). Changes in invertebrate communities caused by deposited sediment can be difficult to isolate and quantify because they often accompany other modifications in the stream such as removal of riparian vegetation, alterations of flow and temperature regimes, and nutrient enrichment (Zweig and Rabeni 2001). These community changes can be detrimental to fisheries that depend on macroinvertebrates as primary food supplies and can change the abundance and diversity of fish populations.

Increased sedimentation may also reduce productivity of, or eliminate, rooted and unrooted aquatic vegetation that many species of macroinvertebrates and fish depend on for food and habitat, which may reduce populations of fish and macroinvertebrates. An increase in sediment load in the streams in the Project Area may have an impact on fish and macroinvertebrates and their habitats. Zweig and Rabeni (2001) reported that the density and taxa richness of benthic invertebrates substantially decreased in three of four Missouri study streams well before 30 percent deposited sediment was reached. As deposited sediment increases, the community structure and diversity can also be altered. Community changes generally involve a shift in dominance from *Ephemeroptera*, *Plecoptera*, and *Trichoptera* to oligochaetes in general (Zweig and Rabeni 2001). Management of the riparian zone has a strong influence on the degree that streams behave as sources or sinks of fine sediment (Rabeni and Smale 1995). Using a buffer strip to stabilize channels and collect extra sediment during high flows could be an option for mitigating the effects of siltation on stream fishes and macroinvertebrates within the Project Area.

Receiving waters in streams and rivers may become less turbid because produced water is relatively low in sediments. This decrease could be detrimental to fish that depend on turbid waters and may allow for more aggressive invasion of exotic species. However, most of the species within the Powder River are tolerant of widely fluctuating environmental conditions, such as turbidity. Naturally occurring turbid waters are generally well downstream of CBM discharge points; thus, turbidity would likely be at near-natural levels when CBM discharges enter waters that are more turbid. These effects would be minimal and isolated.

The proposed addition of more than 17,000 miles of new roads within the Project Area would likely lead to increased traffic volumes and subsequently higher amounts of road dust in all sub-watersheds within the Project Area. Roads allow for increased runoff that leads to increased sedimentation. Increased sedimentation from roads would be most noticeable during storm events, for example, when wind blows dust from roads that may enter drainage systems.

Site-specific information on rates of sediment deposition was not available for the watercourses within each sub-watershed. However, based on the assumption that sediment deposition will increase when CBM discharge represents a greater percentage of the minimum monthly flow of the affected main stems within the Project Area, the Upper Tongue River, Salt Creek, Middle Powder River, Upper Powder River, Clear Creek, and Crazy Woman Creek would not be expected to see noticeable increases in sedimentation. Impacts to aquatic species within these watercourses from sediment deposition would be minimal or non-existent. The other seven affected sub-watersheds may see noticeable increases in sedimentation, especially during periods of low flow. These sub-watersheds are the Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River. Aquatic species in these sub-watersheds may be affected, as discussed above, by an increase in sedimentation. Based on the preferred habitats of the fish species found within the Project Area (Table 3–57), it is likely that an increase in sediment loads would favor species such as the black bullhead, common carp, flathead chub, plains killifish, plains minnow, goldeye, river carpsucker, sand shiner, sturgeon chub, and white crappie. Species such as the brassy minnow, common shiner, creek chub, mountain whitefish, northern redhorse, brown trout, brook trout, cutthroat trout, Yellowstone cutthroat trout, rainbow trout, smallmouth bass, and walleye may be negatively affected by an increase in sediment.

TMDL is the amount of pollutant a stream can accept and still meet designated uses. TMDLs must be established for each pollutant, including sediment, that is a source of impairment in the stream. To date, WDEQ has not developed TMDLs for sediment in the sub-watersheds located within the Project Area, but TMDLs may be required for sub-watersheds that show impairments to water quality from increased sediment loads.

Salt Concentrations

Increases in concentrations of salt can alter the algae and macroinvertebrate composition of streams and, if sufficiently elevated, can change the abundance and diversity of fish species. Parameters such as EC, TDS, or salinity are used as a measure of the concentrations of common ions in fresh water (Mount et al 1997). The toxicity of water high in TDS to some aquatic invertebrates depends on the specific ionic composition. Ion imbalance may result from the composition and concentration of anions and cations that make up salinity (Goodfellow et al. 2000). Toxicity is affected by the ionic composition of the effluent as well as the species and life history stage (Chapman et al. 2000 and Pillard et al. 1999). The EPA Phase I Toxicity Identification Evaluation (TIE) can be used to measure concentrations of specific inorganic ions. Most effluent toxicity testing methods generally do not attempt to segregate the effects of salinity or ionic strength on test and species performance based on cost and timing. Mount et al. (1997) developed models to test individual and combined ion toxicity on invertebrates such as *C. dubia* and *D. magna* and vertebrates such as the fathead minnow (*P. promelas*). The models followed the general guidelines of the EPA for conducting acute whole effluent toxicity (WET) tests (EPA 1994). These models can be used to project changes in toxicity that result from modifications in industrial processes, effluent treatment, or other remedial measures. As a general screening tool, the concentration of TDS can be high enough to adversely affect freshwater test species if the conductivity of a freshwater effluent is above 2000 µS/cm (Goodfellow et al. 2000).

Little information exists on toxicity of TDS to organisms other than *C. dubia*, *D. magna* and *P. promelas*; however, Chapman et al. (2000) conducted toxicity tests on rainbow trout (*Oncorhynchus mykiss*) embryos and swim-up fry and larval chironomids (*Chironomus tentans*). No adverse effects were apparent with early life stages of rainbow trout exposed to effluents with concentrations of TDS up to 2,000 mg/L. Chironomids, however, exhibited reduced growth and survival at concentrations of TDS of approximately 2,000 mg/L (Chapman et al. 2000).

Concentrations of TDS typically exceed the secondary drinking water standard of 500 mg/L in most of the Project Area. Nearly 50 percent of the TDS concentrations measured at water quality monitoring stations in the Project Area exceed 2,000 mg/L (Lowry et al. 1986). Benthic macroinvertebrates and fish that inhabit these waters have adapted to these elevated concentrations of TDS. Concentrations of TDS in CBM discharge range between 270 and 2,720 mg/L (Table 3-2). Discharges higher than 2,000 mg/L may cause adverse effects on invertebrates, as described by Chapman et al. (2000).

Salinities projected for CBM produced water differ from the existing receiving waters. When mixing with discharges of CBM produced water, is modeled, salinity, as measured by EC, in receiving waters is predicted to increase in the Upper Tongue River, Crazy Woman Creek, Clear Creek, and Middle Powder River subwatersheds during low flow. Salinity is expected to decrease in the Upper Powder River, Little Powder River, Salt Creek, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds during low flow.

Aquatic species may experience effects from the predicted changes in salinity, as discussed previously in this section. Fish present in Salt Creek, such as the fat-

BEST COPY AVAILABLE

head minnow, flathead chub, longnose dace, plains minnow, sand shiner and white sucker, are all likely tolerant of high salinities and would be more tolerant of increases in salinity in other sub-watersheds. Other species found within the sub-watersheds with lower salinities may be less tolerant of increases in salinity.

A recent study by the Montana Department of Fish, Wildlife, and Parks (Skaar 2001) described concerns relating to sodium bicarbonate toxicity to aquatic life in the Powder and Tongue Rivers. Fish and macroinvertebrates could be negatively affected by elevated levels of bicarbonate in the receiving sub-watersheds. Concentrations of bicarbonate are generally higher during low flow, and lower during high flow, resulting in greater accumulations and enhanced effects on aquatic life during low flow periods. The study suggests that bicarbonate levels should be monitored for their potential effects on aquatic life, especially fish. Low, moderate, and high probability thresholds were modeled for each river to establish lethal limits to the fathead minnow; these limits can then be generally applied to many species of fish. These thresholds could be used to initiate a monitoring program for bicarbonate in the sub-watersheds of the Project Area that would receive CBM produced water.

In addition to salts added directly to surface drainages, CBM produced waters that do not reach drainages would evaporate and deposit salts in soils throughout the sub-watersheds. This accumulation of salts in the soils will continue as long as CBM produced water is discharged and may be released into surface drainages and groundwater for years after the discharge of water ceases, further increasing salinity in surface drainages and potentially affecting fish and macroinvertebrates.

Concentrations of Metals

Some aquatic organisms are able to develop a tolerance to an increased concentration of metals within the surrounding aquatic environment. Explanations to account for increased tolerance to contaminants include physiological acclimation and genetic adaptation (Clements 1999). The physiological and genetic mechanisms responsible for tolerance may come with specific costs. Several studies have documented a tradeoff within individuals between the benefits of tolerance and the associated energetic costs, with consequences for populations and communities (Courtney and Clements 2000, Mackey and McNeilly 1975, Wilson 1988). Clements (1999) reported that both population-level responses and species replacement accounted for greater tolerance to high concentrations of metals of aquatic invertebrates in a stream contaminated by metals. Clements (1999) also hypothesized that chronic exposure of mayflies to a stream contaminated by metals affected their ability to detect or avoid predators, causing predation to increase.

Levels of selenium in CBM produced water in the Project Area are lower than Wyoming water quality standards. Concentrations of selenium were below [illegible] µg/L for all samples tested within the Project Area. All concentrations of trace elements were uniformly low and were below the primary and secondary maximum contaminant levels for drinking water established by EPA. Concentrations of selenium are generally higher during low flow, and lower during high flow, resulting in greater accumulations during low flow. Effects of selenium on fish may range from physical malformations during embryonic development to steriliity and death (Lemly and Smith 1987). Concentrations greater than 2 to 5 μg/L in water can cause reproductive failure or mortality in fish through bioaccumulation in the food chain (Lemly and Smith 1987). Selenium can be absorbed or ingested by organisms, can bind to particulate matter, or can remain free in solution. Selenium usually accumulates in the top layer of sediment and detritus. Selenium can then be cycled back into the biota and remain at elevated levels for years after input has stopped (Lemly and Smith 1987). Generally, flowing waters accumulate less selenium than do standing waters that have low flushing rates, and recovery is much slower in shallow impoundments and wetlands than in fast-flowing rivers and streams (Lemly and Smith 1987).

Although mean concentrations of selenium were measured below specified standards, bioaccumulation may increase as more selenium is introduced into the ecosystem. Selenium could reach harmful levels for fish over the life of the project. It is anticipated that concentrations of selenium in containment impoundments would be higher than in the stream and river systems within the 10 subwatersheds in the Project Area because of evaporative concentration over time. Containment impoundments receiving discharges of CBM produced water would have NPDES monitoring requirements for selenium because of its bioaccumulative nature. Fish and macroinvertebrates that may inhabit ponds and reservoirs that receive CBM produced water may experience effects from bioaccumulation of selenium. Fish and macroinvertebrates in stream and river systems within the affected sub-watersheds may be affected by increased selenium input; however, WDEQ issued NPDES-permits would establish effluent limitations on CBM discharges for selenium and other metals that would be protective of aquatic life.

Water Temperature

Water temperature can affect growth, metabolism, reproduction, emergence, and the distribution of aquatic species (Vannote and Sweeney 1980). The magnitude and pattern of historical, annual, seasonal, and daily fluctuations in temperature may be important in selecting and maintaining a variety of aquatic insects in a stream reach (Vannote and Sweeney 1980). Sudden increases or decreases in water temperature could result in population- and community-level changes in aquatic insects within the Project Area.

The temperature of CBM discharge water varies throughout the Project Area and ranges between 12 and 29°C with a median of 19°C. The temperature of streams within the Project Area can range from 0°C during winter to 25°C or more during summer; therefore, changes in temperature are not expected to be dramatic but would vary depending on the location of CBM discharge.

Spills of Fuel and Drilling Fluid

Spills of fuel and drilling fluid can result in fish and macroinvertebrate kills and degradation of habitat. The severity and scope of a stream kill would depend on the volume spilled, the distance of the spill from surface water, and the chemical and toxicological properties of the materials spilled. BMPs outlined in the APD permitting process would help limit the number of spills of fuel and drilling fluid.

BEST COPY AVAILABLE

Species Diversity

As previously discussed, the effects of CBM on aquatic species, such as changes in water flow, temperature, sedimentation, turbidity, and concentrations of salts and metals, could have an effect on all four levels of biodiversity (genetic, population/species, community/ecosystem, and landscape). The severity of these effects would increase as these conditions remain altered for longer periods. The longer CBM produced waters enters drainages, the higher the probability for substantial effects to species diversity over large portions of drainages. Potential changes in species diversity would be the greatest under Alternative 1 because this alternative would have the greatest impact on aquatic ecosystems.

Trans-boundary Water Quality Effects

The states of Wyoming and Montana have developed an Interim Water Quality Criteria MOC, which states that water quality in streams and rivers that enter Montana from Wyoming will not exceed set limits for toxicity caused by CBM produced water discharged in Wyoming. Sufficient mitigation measures would be in place to ensure that water quality would not be degraded substantially at the border between Wyoming and Montana (Appendix B).

Alternative 2A

Under Alternative 2A, the same number of CBM wells and the same volume of water production would occur as under Alternative 1. Alternative 2A involves different handling techniques for the produced water in certain sub-watersheds, emphasizing discharge of CBM water to infiltration impoundments. Approximately 31 percent of the proposed wells would discharge produced water on the surface and 55 percent would discharge produced water to infiltration reservoirs. Thus, the volume of water discharged to surface drainages would be less than under Alternative 1. Ten of 18 sub-watersheds would receive produced water under this alternative. Effects to water quality would be similar to Alternative 1, but the magnitude would be proportionately lower because of the reduction in the volume of produced water discharged to surface drainages.

Timing and Quantity of Stream Flows

Stream flows supplemented by CBM water would increase by varying degrees from baseline conditions under Alternative 2A. The Upper Tongue River, Salt Creek, Crazy Woman Creek, and Clear Creek sub-watersheds would not see noticeable increases in stream flows during low flow. The Upper Powder River, Middle Powder River, Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds may see noticeable increases in stream flows during low flow. Aquatic species in these sub-watersheds may be affected, as discussed above under Alternative 1; however, the degree of [illegible] would be substantially less under Alternative 2A than under Alternative 1.

Sedimentation

Because a smaller volume of CBM produced water would be discharged to surface drainages under Alternative 2A, the degree of sedimentation in rivers and streams would be less than under Alternative 1, although the types of potential impacts would be similar.

215

The Upper Tongue River, Salt Creek, Middle Powder River, Upper Powder River, Clear Creek, and Crazy Woman Creek would not see noticeable increases in stream flows during low flow or increased sedimentation, and impacts to aquatic species would be minimal or non-existent. The Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds may see noticeable increases in sediment loads. Aquatic species in these sub-watersheds may be affected, as discussed above, by an increase in sedimentation, but impacts would be substantially less than under Alternative 1.

Concentrations of Salt

Changes in concentrations of salt in surface waters that receive CBM produced water would also be less under Alternative 2A than under Alternative 1, although the types of potential impacts would be similar. Salinity would change as described under Alternative 1, but to a lesser degree under Alternative 2A. Related impacts to fish and macroinvertebrates would therefore be less under Alternative 2A.

Metals

Changes in concentrations of metals in surface waters that receive CBM produced water would also be less under Alternative 2A than under Alternative 1, although the types of potential impacts would be similar. Concentrations of metals would change as described under Alternative 1, but to a lesser degree under Alternative 2A. Related impacts to fish and macroinvertebrates would therefore be less under Alternative 2A.

Spills of Fuel and Drilling Fluid

The potential for spills of fuel and drilling fluid to affect fish and macroinvertebrates would be reduced under Alternative 2A compared with Alternative 1 because less CBM produced water would be available to convey pollutants to surface drainages.

Species Diversity

As previously discussed, the effects of CBM activities on aquatic species, such as changes in water flow, temperature, sedimentation, turbidity, and concentrations of salts and metals, could have an effect on all four levels of biodiversity (genetic, population/species, community/ecosystem, and landscape). The severity of these effects would increase as these conditions remain altered for longer periods. The longer CBM produced waters enter drainages, the greater the probability for substantial effects to species diversity over large portions of drainages. Potential changes in species diversity would be similar under Alternative 2A to Alternative 1, although they would occur at a lesser degree because of the reduction in impacts to aquatic ecosystems under this alternative.

Alternative 2B

Under Alternative 2B, the same number of CBM wells and the same volume of water production would be projected as under Alternative 1. Alternative 2B involves different methods of handling the produced water in certain sub-watersheds, emphasizing active treatment and discharge to infiltration impoundments. Approximately 45 percent of the proposed wells would discharge pro-

216

duced water on the surface and 39 percent would discharge produced water to infiltration reservoirs. Ten of 18 sub-watersheds would receive produced water. Effects to water quality would be similar to Alternative 1, but proportionately lower because of the reduction in the volume of produced water discharged to surface drainages and the proportion of water to undergo active treatment.

Timing and Quantity of Stream Flows

Flows supplemented by CBM produced water would increase from baseline conditions under Alternative 2B. The Upper Tongue River, Salt Creek, Clear Creek, and Crazy Woman Creek sub-watersheds would not see noticeable increases in stream flows during low flow. The Upper Powder River, Middle Powder River, Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds may see noticeable increases in stream flows during low flow. Aquatic species in these sub-watersheds may be affected, as discussed above under Alternative 1; however, the degree of the effect would be less under Alternative 2B than under Alternative 1.

Sedimentation

Because a smaller volume of CBM produced water would be discharged to surface drainages under Alternative 2B, the degree of sedimentation in rivers and streams would be less than under Alternative 1, although the types of potential impacts would be similar. The Upper Tongue River, Upper Powder River, Salt Creek, Crazy Woman Creek, Clear Creek, and Middle Powder River would not see noticeable increases in sedimentation and impacts to aquatic species would be minimal or non-existent. The Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds may see noticeable increases in sediment loads. Aquatic species in these sub-watersheds may be affected, as discussed above, by an increase in sedimentation, but impacts would be substantially less than under Alternative 1.

Concentrations of Salt

Changes in concentrations of salt in surface waters that receive CBM produced water would be less under Alternative 2B than under Alternative 1, although the types of potential impacts would be similar. Salinity would change as described under Alternative 1, but these changes would occur to a lesser degree under Alternative 2B because of the proportion of water to undergo active treatment. Related impacts to fish and macroinvertebrates would therefore be less under Alternative 2B than under Alternative 1.

Metals

Changes in concentrations of metals in surface waters that receive CBM produced water would be less under Alternative 2B than under Alternative 1, although the types of potential impacts would be similar. Concentrations of metals would change as described under Alternative 1, but to a lesser degree under Alternative 2B because of the proportion of water to undergo active treatment. Related impacts to fish and macroinvertebrates would therefore be less under Alternative 2B.

Spills of Fuel and Drilling Fluid

The potential for spills of fuel and drilling fluid to affect fish and macroinvertebrates would be reduced under Alternative 2B compared with Alternative 1 because less CBM produced water would be available to convey pollutants to surface drainages.

Species Diversity

As previously discussed, the effects of CBM activities on aquatic species, such as changes in water flow, temperature, sedimentation, turbidity, and concentrations of salts and metals, could have an effect on all four levels of biodiversity (genetic, population/species, community/ecosystem, and landscape). The severity of these effects would increase as these conditions remain altered for longer periods. The longer CBM produced waters enters drainages, the greater the probability for substantial effects to species diversity over large portions of drainages. Potential changes in species diversity would be similar under Alternative 2B to Alternative 1, although they would occur at a lesser degree because of the reduction in impacts to aquatic ecosystems under this alternative.

Alternative 3

Under Alternative 3, no new CBM wells would be completed on federal leases within the Project Area. The proportions of the various methods of water handling would be the same as under Alternative 1. Water production would be less under Alternative 3 than under Alternative 1. Thus, the volume of water discharged to surface drainages would be less than under Alternatives 1, 2A, and 2B. Ten of 18 sub-watersheds would receive produced water. Approximately 54 percent of the proposed wells would discharge produced water on the surface and 29 percent would discharge produced water to infiltration reservoirs. Effects to water quality would be similar to Alternative 1, but would be proportionately lower based on the reduction in the volume of produced water discharged to surface drainages.

Timing and Quantity of Stream Flows

Flows supplemented by CBM produced water would increase slightly from baseline conditions under Alternative 3. The Upper Tongue River, Salt Creek, Crazy Woman Creek, and Clear Creek sub-watersheds would not see noticeable increases in stream flows during low flow. The Upper Powder River, Middle Powder River, Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River sub-watersheds may see noticeable increases in stream flows during low flow. Aquatic species in these sub-watersheds would be affected, as discussed above under Alternative 1; however, the degree of the effect would be substantially less under Alternative 3 than under Alternative 1.

Sedimentation

Because a smaller volume of CBM produced water would be discharged to surface drainages under Alternative 3, the degree of sedimentation in rivers and streams would be substantially less than under Alternative 1, although the types of potential impacts would be similar. Noticeable increases in sedimentation would not be expected for the Upper Tongue River, Salt Creek, Crazy Woman Creek, Upper Powder River, and Middle Powder River sub-watersheds during low flows. Impacts to aquatic species within these streams from deposition of sediment would be minimal or non-existent. The Little Powder River, Antelope Creek, Upper Cheyenne River and Upper Belle Fourche River sub-watersheds may see noticeable increases in sediment loads during low flows. Aquatic species in these sub-watersheds may be affected, as discussed above, by an increase in sedimentation, but impacts would be substantially less than under Alternative 1.

Concentrations of Salt

Changes in concentrations of salt in surface waters that receive CBM produced water would be less under Alternative 3 than under Alternative 1, although the types of potential impacts would be similar. Salinity would change as described under Alternative 1, but to a lesser degree under Alternative 3. Related impacts to fish and macroinvertebrates would therefore be less under Alternative 3 than under Alternative 1.

Metals

Changes in concentrations of metals in surface waters that receive produced water would be less under Alternative 3 than under Alternative 1, although the types of potential impacts would be similar. Concentrations of metals would change as described under Alternative 1, but to a lesser degree under Alternative 3. Related impacts to fish and macroinvertebrates would therefore be less under Alternative 3.

Spills of Fuel and Drilling Fluid

The potential for spills of fuel and drilling fluid to affect fish and macroinvertebrates would be reduced under Alternative 3 compared with Alternative 1 because less CBM produced water would be available to convey pollutants to surface drainages.

Species Diversity

As previously discussed, the effects of CBM activities on aquatic species, such as changes in water flow, temperature, sedimentation, turbidity, and concentrations of salts and metals, could have an effect on all four levels of biodiversity (genetic, population/species, community/ecosystem, and landscape). The severity of these effects would increase as these conditions remain altered for longer periods. The longer CBM produced waters enter drainages, the greater the probability for substantial effects to species diversity over large portions of drainages. Potential changes in species diversity would be similar under Alternative 3 to Alternative 1, although they would occur at a lesser degree because of the reduction in impacts to aquatic ecosystems under this alternative.

Cumulative Effects

Current major land uses in the Project Area include livestock grazing, agriculture, mining, CBM gas development, and conventional oil and gas development. The proposed project would contribute to ongoing effects to aquatic life from all of these land uses. Implementation of each of the alternatives would contribute to cumulative effects on aquatic species in the Project Area. The proposed alternatives, combined with the potential for future CBM projects that are not addressed in this document, may lead to potential cumulative effects that include fluctuations in stream flow, fluctuations in sedimentation, increases in concentrations of salt, increases in contaminants in waterways, and changes in water quality, habitats, and species diversity. Each alternative would contribute to cumulative effects in varying degrees, as discussed above.

In addition to an increase in flow in the sub-watersheds that receive CBM produced waters, coal mines in the Project Area discharge water from pits into surface drainages. Coal mine records for the Project Area indicate that water is generally discharged from pits only after storms, when the quality of the coal mine discharge water is similar to the quality of receiving water. These discharges would not affect sedimentation or water quality to a large degree, but would add to already increased instream flows during high runoff. Coal mines are located in sub-watersheds within the Project Area that include Upper Cheyenne River, Upper Belle Fourche River, and Little Powder River. These cumulative impacts would affect aquatic species in the same ways as were discussed above. After CBM development is completed, flows would return to the current regime.

The proposed project would lead to an overall increase in sediment load in drainages within the Project Area and would contribute to increased sedimentation caused by existing land uses in the area. Increased flow of CBM produced water and sedimentation related to construction of new roads would be the primary contributor to increased sediment load in drainage systems. Much of the sediment produced by the project would be collected in ponds and reservoirs throughout the Project Area and would likely be flushed through the drainage systems for years after discharge of CBM water ceased. Increased sediment load may also change or eliminate existing habitats for fish and macroinvertebrate over the long term; these changes in habitat may favor exotic species over native species.

Agriculture and livestock grazing are currently the primary sources that introduce salt to surface drainages, and CBM produced waters would contribute additional salts. In addition to salts added directly to surface drainages, CBM produced waters that do not reach drainages (for example, as a result of containment, LAD, and injection) will evaporate and deposit salts in soils throughout the sub-watersheds. This accumulation of salts in the soils will continue as long as CBM produced water is discharged. These salts and may be released into surface drainages and groundwater for years after discharge of water ceases, further increasing salinity in surface drainages and potentially affecting fish and macroinvertebrates.

Water quality would continue to change throughout the Project Area both during and after the life of the project and potentially would continue to affect aquatic life in drainages already affected by existing land uses. Long-term effects to water quality that would continue after CBM wells cease discharging could include increased concentrations of selenium, bicarbonate, and other salts, and sediment load. Project adherence to WDEQ-issued NPDES requirements are expected to minimize long-term effects to water quality and aquatic life. Because sub-watersheds in the Project Area would be subjected to a variety of chemical stressors during CBM development and production, potential interactions between effluents high in TDS may negatively affect a variety of aquatic species. In specific cases where acute effects on aquatic organisms are observed, evaluation of the composition of the water using both salinity and single-ion models may be a way of quickly screening effluents for potential ion-related toxicity (Pillard et al. 1999).

All of the cumulative effects may influence current species diversities of fish and macroinvertebrates. Long-term cumulative effects may alter water quality and fish habitats to the extent that exotic species can inhabit these streams and rivers more effectively than native species, leaving more exotic species and fewer native species.

Alternative 1

Under Alternative 1, cumulative effects would be highest in the Antelope Creek, Upper Belle Fourche River, Upper Cheyenne River, Little Powder River, Upper Powder River, Crazy Woman Creek, Clear Creek, Middle Powder River, Upper Tongue River, and Salt Creek sub-watersheds. This conclusion is based on the increase in surface water flows caused by discharge of CBM produced water and the percentage of CBM discharge in relation to the minimum monthly flow. Development of new roads would also contribute to cumulative effects in sub-watersheds that would not receive discharged CBM water. Alternative 1 would have the most cumulative impacts of the three alternatives.

Alternative 2A

Under Alternative 2A, cumulative effects would affect the same sub-watersheds as Alternative 1. Although the types of potential impacts would be similar, cumulative overall impacts would be greater under Alternative 2A than Alternatives 2B and 3, but less than Alternative 1. This conclusion is based on the increase in surface water flows caused by discharge of CBM produced water and the percentage of CBM discharge in relation to the minimum monthly flow. Development of new roads would also contribute to cumulative effects in watersheds that would not receive discharged CBM water.

Alternative 2B

Under Alternative 2B, cumulative effects would affect the same sub-watersheds as Alternatives 1 and 2A. Although the types of potential impacts would be similar, cumulative overall impacts would be greater under Alternative 2B than Alternative 3, but less than Alternatives 1 and 2A. This conclusion is based on the increase in surface water flows caused by discharge of CBM produced water and the percentage of CBM discharge in relation to the minimum monthly flow. Development of new roads would also contribute to cumulative effects in watersheds that would not receive discharged CBM water.

Alternative 3

Under Alternative 3, cumulative effects would affect the same sub-watersheds as Alternatives 1, 2A, and 2B. Although the types of potential impacts would be similar, cumulative overall impacts would be less under Alternative 3 than Alternatives 1, 2A, and 2B. This conclusion is based on the increase in surface water flows caused by discharge of CBM produced water and the percentage of CBM discharge in relation to the minimum monthly flow. Development of new roads would also contribute to cumulative effects in watersheds that would not receive discharged CBM water.

Threatened, Endangered, or Sensitive Species

Potential effects to threatened, endangered, or sensitive (special-status) species would be similar to those described for vegetation and wildlife. The nature and extent of effects to a specific species would depend on life history and habitats used. Direct effects to special status plant species would occur from disturbance or removal of individuals or populations from construction of well pads, compressor stations, ancillary facilities, associated pipelines, water-handling facilities, and roads. Indirect effects to special status plant species would include an increase in the potential for introduction and spread of noxious weeds that may displace native plants, and alteration or destruction of suitable habitats caused by changes in water quality and quantity.

Effects to special-status wildlife species would include: (1) direct injury or mortality, including poaching, poisoning or trapping; (2) indirect injury or mortality, including effects from water disposal, electrocution by or collisions with aboveground utility lines and poles, and collisions with vehicles; (3) harassment or displacement of individuals during project phases; and (4) direct disturbance, destruction, or fragmentation of habitats as the result of development and production activities, including water disposal, that may change the availability and effectiveness of the habitat. The magnitude of effects to special status species would depend on a number of factors, including recommended and required mitigation measures.

Direct disturbance to the habitats of special-status species would occur in each of the 18 sub-watersheds and under each alternative. Indirect effects, including displacement, would occur in varying degrees during the construction, production, and decommissioning and abandonment phases of the project. Species would avoid areas and move to other locations in response to the increased levels of human activity, equipment operation, vehicular traffic, and noise associated with all phases of the project. This avoidance could result in the under use of otherwise suitable habitats depending on the extent of the disturbance (in both time and space). The value of these habitats could be diminished. Additionally, distribution patterns could be altered and competition for resources could be increased in unaffected habitats. The degree of habitat avoidance would vary among species and among individuals of any species. Mitigation measures expected to eliminate or minimize potential effects to threatened and endangered wildlife and plant species are provided at the end of this chapter.

The comparison of Alternatives 1, 2A, and 2B is solely based on acres of surface disturbance that result from water disposal because of the equivalent number of proposed wells, roads, and other facilities. Alternatives 1, 2A, and 2B each propose similar numbers of CBM and non-CBM wells. Therefore, potential effects to habitats of special-status species would be similar. Disturbances that result from methods of water handling are not equal among these alternatives. Alternative 1 would affect 27,009 acres, Alternative 2A would affect 36,263 acres, and Alternative 2B would affect 32,653 acres. Alternative 3 differs from these alternatives by proposing a lower number of wells, roads, and facilities, and subsequently requiring a lower capacity for disposal of water. Alternative 3 would result in the addition of fewer CBM and non-CBM wells, resulting in effects to 38 percent fewer total acres than Alternatives 1, 2A, and 2B. Methods of water

244

handling under Alternative 3 would result in the disturbance of 14,384 acres (between 40 and 53 percent of Alternatives 1, 2A, and 2B) that could affect habitat for sensitive species, which is also less than the other three alternatives. In addition to the discussions below, more detail on the analysis of listed species is included in Appendix J (Biological Assessment) and Appendix K (Biological Opinion).

Species Listed by USFWS

Black-footed Ferret

The potential for direct effects to the black-footed ferret is minimal. No populations of this species are known in the Project Area. However, disturbance to potential black-footed ferret habitats that exist within black-tailed prairie dog colonies would occur. Most of the larger prairie dog colonies that would be capable of supporting ferret populations have been surveyed to rule out the presence of the ferret. Any colonies that meet USFWS' guidelines for potential black-footed ferret habitat, and that have not been previously surveyed, would be surveyed for ferrets. No activities would occur in any colonies contain ferrets.

Bald Eagle

Injury or Mortality

Bald eagles may be affected in several ways. Construction would not cause direct injury or mortality to bald eagles because eagles would not be in close proximity to construction. Mitigation measures included as part of the action would limit new surface disturbance and occupancy in bald eagle nesting and winter roosting habitats, further minimizing the potential for direct injury or mortality to individual eagles. Another source of injury or mortality to eagles may be from intentional or unintentional shooting, poisoning, or trapping. Because the project would result in an increase opportunity for exposure of bald eagles to humans, these sources of injury or mortality may increase over existing, pre-project levels.

Utility Line Electrocution and Collisions

Construction of aboveground power lines may result in collisions or electrocutions causing injury or mortality to bald eagles. Since 1997, the number of reported collisions and electrocutions for bald eagles and golden eagles in the PRB has steadily increased (Seacross 2002). Several specific measures have been included as part of the proposed action to minimize the potential for collision or electrocution, such as: (1) burial of utility lines, if possible; (2) avoidance of areas where raptors may frequently hunt (for example: wetlands, prairie dog towns, and sage grouse habitat), and (3) application of APLIC (1994, 1996) standards to line spacing, conductor layout, and utility pole construction. A monitoring program intended to evaluate the effectiveness of these mitigation measures would be included as part of the proposed action. Information from the monitoring program would be used to evaluate and modify, if necessary, these mitigation measures.

BLANK PAGE

Vehicle Collisions

Bald eagles may experience injury or mortality through collisions with vehicles. The number of bald eagle collisions with vehicles may increase in the Project Area as the result of the increase in traffic. Increases in the volume of traffic would result in an increase in roadside carrion on which bald eagles commonly feed. Traffic is expected to be the greatest during the construction phase and to diminish during the production and decommissioning and abandonment phases to levels similar to pre-project conditions. As part of this alternative, mitigation measures have been proposed to monitor carrion along roadways with the intent of evaluating potential risks to bald eagles and other raptors. An additional measure would restrict the maximum design speed of all operator constructed and maintained roads to 25 mph to minimize the potential for collisions with wildlife and eagles.

Habitat Disturbance or Destruction

New surface disturbance to bald eagle nesting and winter roosting areas would be restricted within specific buffer zones and during specific times. In some cases, direct physical disturbance caused by construction of a road or buried utility line may occur in habitats suitable for nesting and winter roosting. This disturbance would be uncommon and would occur only if no other alignments were available. The proposed project would comply with site-specific timing limitations and mitigation measures for surface disturbance as identified during project specific consultation with the USFWS. Nesting and roosting habitats may also exhibit effects caused by changes in local water quality and quantity that would result from disposal of water. Construction of project facilities, including well pads, compressor stations, roads, and surface water impoundments, would disturb or destroy a variety of terrestrial habitats, including some that may be suitable for foraging by bald eagles. The project would disturb or destroy terrestrial habitats that support typical prey. Some species of prey may respond positively to these changes in the habitat, whereas others may experience negative effects. Overall, the collective distribution and occurrence of prey for the bald eagle throughout the Project Area would not experience effects at a scale sufficient to reduce overall availability.

Methods for disposal of water may affect aquatic habitats used for foraging by bald eagles. The effects of the increased volume of water as the result of the various disposal methods may disturb, destroy, augment, or create aquatic foraging habitats for the bald eagle. The increased volume of water may disrupt aquatic environments that lead to changes in the local occurrence of fish and waterfowl. Conversely, an increased volume of water may improve habitats that were previously unsuitable for fish or waterfowl. These changes may expand or create new aquatic habitats for foraging bald eagles. The potential effects to terrestrial and aquatic foraging habitats would not result in detrimental changes to the condition or reproductive status of individual eagles or affect the status of or trend in the population of bald eagles in Wyoming.

The potential for fragmentation of habitats to affect a species is relevant when it occurs at a scale similar to the species and therefore potentially alters life history processes (for example, restricts movement or creates ineffective habitat patches). Fragmentation of habitats associated with the project would not limit

224

BEST COPY AVAILABLE

movement of bald eagles or result in habitat patches that are unsuitable for foraging bald eagles.

Human Disturbance

Many of the eagles that occur in the Project Area may be unaccustomed to human activity because of the current lack of human activity throughout most of this area. Nesting and winter roosting eagles can exhibit heightened sensitivity to human disturbances, whereas foraging eagles are relatively less sensitive (Steenhof 1978). The project, including new surface disturbance associated with construction, production, and decommissioning and abandonment, would harass or displace nesting, winter roosting, or foraging bald eagles. Included as part of the project are measures that would eliminate human presence within 1 mile of nesting and winter roosting areas during the appropriate seasons. Depending on the type of activity, time of year, disposition of the eagle, and previous exposure to human activity, these measures may vary in their effectiveness. Consequently, monitoring of bald eagle nests and roosts would occur (Appendix D). Results of the monitoring would be used to evaluate and modify, if necessary, mitigation measures specific to bald eagles. The relative widespread occurrence of terrestrial foraging habitats in the Project Area and the diffuse nature of the expected human activity would not cause detrimental changes to terrestrial foraging patterns for the bald eagle. Most human activity would be associated with construction of project facilities, but would then diminish during the operation and decomissioning and abandonment phases. Human activities would be the lowest during the production phase and can be characterized as regular and low intensity. During decommissioning and abandonment of facilities, local levels of activity would temporarily increase for a period sufficient to complete habitat restoration.

Ute Ladies'-tresses Orchid

The potential for direct effects to this species would be minimal. No oil or gas wells currently exist in the upper portion of the Antelope Creek sub-watershed near the only known occurrence of this species within the Project Area. None of the wells that are proposed as a part of this project would be constructed near that location.

However, the potential exists for other populations of this species to occur in the Project Area. Surveys of potentially suitable habitats (wetlands and riparian areas) would be required before construction begins. In addition, efforts would be made to avoid habitats that are suitable for this species. Because of the ability of this species to persist below ground or aboveground without flowering, single-season surveys that meet USFWS' current guidelines may not detect populations. As a result, part or all of undetected populations could be lost through actions that disturb the surface.

If unknown populations of this species exist in the Project Area, they could be affected by hydrological alterations associated with the project. The discharge of produced water could alter the distribution and extent of riparian and wetland areas, and the net effect could be an increase in their extent. This increased extent may provide additional habitat for the Ute ladies'-tresses orchid in areas that are not currently suitable, while at the same time rendering some current habitat unsuitable. Pumping of CBM wells could lower groundwater tables and causing a

225

loss of riparian and wetland vegetation in isolated areas where coal seams are near shallow alluvium. In some situations, the level of groundwater may be supplemented and not depleted depending on the methods used for handling the produced water. Increases in levels of groundwater may augment existing or create new habitats. Effects along any drainage would depend on the amount, timing, and location of water discharge, stream geomorphology, precipitation, and other factors. Habitats and populations of this species may be affected by increased erosion or sediment deposition. Some streams would be greatly affected by discharge, while others would be affected only minimally or not at all.

Both direct and indirect disturbances to populations and habitats of the Ute ladies'-tresses orchid have the potential to increase the distribution and extent of noxious weeds, such as Canada thistle, that occur in similar habitats. Dense populations of noxious weeds would reduce the amount of habitats available to the orchid and could exclude the orchid from infested areas.

Preble's Meadow Jumping Mouse

This species would not be affected by the project because it does not occur in parts of the Project Area that would be affected by development. Discharge of produced water to the North Platte River would not affect the overall hydrologic regime of this large river system, which is where the occurrence of this species has been documented.

Mountain Plover

The project has the potential to cause direct and indirect effects to the mountain plover. Direct disturbance or destruction of nests and injury or mortality to individuals may occur as a result of vehicle collisions and equipment operation in nesting areas. A requirement for surveys of all habitats potentially suitable for mountain plovers would occur before any ground disturbing activities begin. Following USFWS' guidelines (USFWS 2002b), these surveys would identify the presence of nesting mountain plovers and active nests in all areas to be developed. Results of these surveys would be used to establish appropriate buffers around identified nests. These efforts would minimize direct injury and mortality to mountain plover eggs, chicks, or adults. Additionally, USFWS identified a variety of mitigation measures for protecting the mountain plover. These measures are identified in the mitigation section, which begins on page 4–400.

Mountain plovers are known to occupy suitable microhabitats in the Project Area (for example; flat terrain, patches of bare ground with vegetation less than 4 inches in height) within the short-grass prairie and sagebrush-grasslands vegetation types. As many as 55,540 acres of short-grass prairie and sagebrush grasslands would be disturbed by construction of project facilities. This estimate represents 1 percent of the total 5,507,953 acres of short-grass prairie and sagebrush grasslands within the Project Area. Identification and avoidance of mountain plover nesting areas and minimization of disturbance to prairie dog colonies would reduce the potential for disturbing mountain plover habitats. Habitats that may be suitable for mountain plovers but determined to be unoccupied would experience some degree of disturbance as the result of project-related activities. The acreage is difficult to quantify because of the variety of factors that control the amount of potential disturbance in any habitat, including the distribution and

JHC

proportion of habitats in relation to the proposed, but unmapped, development. Disturbances of mountain plover habitat would be reclaimed after the project ends. Reports of take combined with results of pre-construction surveys would contribute to the understanding of the occurrence of mountain plovers and their habitats within the Project Area and support evaluation and modification, if necessary, of mitigation measures for the mountain plover.

Preferred nesting habitats, such as bare soil, may be created by the project. Although they would provide habitats, these areas are also likely cause nests to be abandoned or destroyed when activities continue during the nesting season. The potential for this type of impact to occur would be greatest during the production phase, when limited intermittent activity would occur at well pads and along some access roads. Mountain plovers may arrive and begin nesting on bare ground in these areas, only to be disturbed or have their nests destroyed when the road is used or the well pad is visited. This impact is most likely when activities occur at an interval of one week or more. During the construction phase, continuous activity is likely to prevent establishment of the nest.

Chicks and eggs in nests may be lost if harassment or displacement occurs frequently, preventing adults from tending to chicks or nests and allowing excessive heating, chilling, or predation to occur. Frequent harassment or displacement may lead to abandonment of the nest. Re-nesting may take place, but a net loss in reproductive potential would have occurred because of the loss of the initial nest. Mountain plovers also show a high rate of fidelity to the nest site, often using the same general area year after year. Modifications that make these areas less suitable for nesting may result in decreased reproductive success. New nests may be built in habitats that are less suitable, again potentially resulting in lower reproductive success. Requiring pre-construction surveys of potentially suitable mountain plover habitats would be used to identify active nesting areas and to establish buffer zones around them to prevent injury or mortality and minimize loss of occupied nesting habitats.

Project-related activities, particularly human presence in areas that are typically void of human activity, may result in increased predation of mountain plovers. This increased potential for predation would primarily involve species that benefit from human disturbance, such as corvids (crows, ravens, and magpies), raptors, coyotes, badgers, weasels, and foxes. Construction of project facilities has the potential to provide nesting, denning, and perching sites for species that prey on the mountain plover. Installation of devices to prevent raptors from perching on project facilities would minimize the addition of perching sites. Additionally, project facilities would be maintained to limit denning opportunities for terrestrial predators. The presence of roadside carrion would also be monitored in an effort to avoid attracting predators that may also prey on mountain plovers and to document potential changes in the occurrence of roadside carrion caused by implementation of the alternative.

Black-tailed Prairie Dog

Disturbance would occur in areas that are suitable for prairie dogs. Direct injury or mortality may occur as a result of the proposed action. Injuries or mortalities may occur to prairie dogs that forage outside of the colony, which puts them at risk of being struck by vehicle or construction traffic. Construction of project facilities could provide new perches for raptors and habitatas for mammalian predator. However, potential perch sites could be modified to prevent raptors from perching and project facilities could be maintained to minimize the availability of potential denning sites for terrestrial predators.

Habitat disturbance, destruction, and fragmentation have been identified as important causes in the decline of prairie dog populations. Habitat loss and fragmentation would reduce the availability of suitable habitats and may lead to potential reductions in reproductive potential in and likelihood of colony expansion. Shifts in vegetation types as a result of discharges of produced water would reduce the amount of habitat available because prairie dogs do not construct burrows in wet or saturated soils. Expanded wetland and riparian areas within colonies would increase fragmentation and decrease effectiveness of the habitat. Avoidance of physical disturbance, including habitat alteration by water handling facilities or discharge, to prairie dog colonies would minimize these potential effects. Changes to existing, unoccupied habitats may limit the potential for expansion of the prairie dog habitat, but would not affect existing colonies.

Throughout the PRB, the potential for methane migration and seepage exists (see Chapter 3, Geology); however, the likelihood for methane seepage to affect prairie dogs or other flora and fauna is considered low. Methane seepage can occur at naturally occurring near-surface coal seams and from inadequate well control procedures and faulty well casing or plugging. Activities related to implementation of the project are not expected to alter the current seepage potential or rates to levels that may be detrimental to prairie dogs or other flora and fauna.

Sylvatic plague is a naturally occurring disease that can affect prairie dogs. The plague is caused by a bacterium that is transmitted by fleas. Prairie dogs are particularly susceptible to the disease with a mortality rate of nearly 100 percent. Surviving individuals do not acquire unique immunities or antibodies, but have simply avoided direct exposure to other diseased animals or vectors. Wild animals serve as unaffected reservoirs for the disease. The disease is contracted by coming in contact with infected animals or fleas. The transmission of the plague to previously uninfected prairie dog colonies as a result of project implementation would be unlikely. Increased human presence in areas otherwise void of human activity is not expected to be an effective vector for the plague between prairie dog colonies. Direct contact between humans and prairie dogs is uncommon. In instances when contact may be possible, humans do not provide suitable host conditions for fleas and, therefore, are not considered effective vectors. It is possible that, as a result of development in otherwise undisturbed areas, wildlife occurrence patterns could change, which could subsequently expose previously unexposed populations to the disease and its vectors. Based on the widespread occurrence of the plague throughout much of Wyoming and the Project Area, this scenario is unlikely.

Boreal Toad

This species would not be affected by the project because it is not known to occur in the Project Area. Historically occupied habitats are located south of, and at a much higher elevation than, the Project Area. Indirect effects to this non-migratory species are not expected. Hydrological alterations to suitable habitats for the boreal toad would not occur because of the lack of hydrologic connectivity between the Project Area and these habitats.

FS, BLM, and WGFD Sensitive Species

Many of the BLM, FS, and WGFD Sensitive species that occur in the Project Area may be affected by the proposed project. The extent of effects to any specific species depends on its life history, habitat preferences, adaptability to disturbance, and population levels in the portion of the Project Area that would be affected. Because populations of many sensitive species in the Project Area are unknown and because the relationship between occupied areas and proposed project activities is unknown, only the general types and levels of impacts can be identified. Table 4-57 lists the potential impacts of the proposed project and estimates the effect for each species. Mitigation measures for threatened and endangered species may benefit sensitive species where their habitats overlap. Although potential impacts to sensitive species and their habitats would be avoided, where practical, impacts are likely to occur because of the lack of specific mitigation measures for these species.

One sensitive species, the greater sage grouse, was identified during project scoping as of particular concern in the Project Area. For this reason, the potential impacts of the proposed project are discussed in more detail for this species than for other sensitive species.

Greater Sage Grouse

Activities associated with the proposed project would affect sage grouse in several ways. These effects may include: (1) increased direct mortality (including legal hunting, poaching, and collision with power lines and vehicles); (2) the introduction of new perches for raptors and thus a potential change in rate of predation; (3) direct loss or degradation of habitats; (4) indirect disturbance resulting from human activity (including harassment, displacement, and noise); (5) habitat fragmentation (particularly through construction of roads); and (6) changes in population. Each of these effects is discussed below.

Alternative 1

Direct Mortality

Sage grouse are legally hunted in the Project Area and poaching likely occurs as well. Regulated hunting of sage grouse, particularly in late September as in the Project Area, probably does not have substantial effects on the size of the population (Connelly et al. 2000, Lyon 2000). Closing hunting seasons has not been documented to result in increased populations (WGFD 2002). The new roads that would be constructed would provide increased access to both public and private lands in the Project Area. Increased access to public lands would result in greater use of these areas by hunters and legal hunting pressure and poaching may increase. Private landowners would continue to control access to, and hunting on, split estate and private lands. Nevertheless, some increased level of poaching may occur because of the sparsely populated nature of the Project Area. This impact is expected to have a minimal effect on sage grouse because of the high proportion of private lands where new public access would not be created.

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

Species Name	Listing Agency	Potential Effects	Population Determination			
			Alt. 1	Alt. 2A	Alt. 2B	Alt. 3
Plants						
Laramie columbine	BLM	Not known to occur in Project Area.	No effect	No effect	No effect	No effect
Porter's sagebrush	BLM	No activities would occur in occupied portion of Project Area.	No effect	No effect	No effect	No effect
Nelson's milkvetch	BLM	Individual plants may be disturbed or destroyed during development and production. Entire populations are unlikely to be destroyed.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Many-stemmed spider flower	BLM	Not known to occur in Project Area.	No effect	No effect	No effect	No effect
William's water parsnip	BLM	No activities would occur in occupied portion of Project Area.	No effect	No effect	No effect	No effect
Laramie false sagebrush	BLM	Not known to occur in Project Area.	No effect	No effect	No effect	No effect
Amphibians						
Tiger salamander	FS	Individual injury or mortality may occur as the result of the project, including water disposal. Breeding habitats may be disturbed, destroyed, augmented, or created as the result of disposal of water.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Spotted frog	BLM	Individual injury or mortality may occur as the result of the project, including disposal of water. Breeding habitats may be disturbed, destroyed, augmented, or created as the result of disposal of water.	No effect	No effect	No effect	No effect
Northern leopard frog	FS, BLM	Individual injury or mortality may occur as the result of the project, including disposal of water. Breeding habitats may be disturbed, destroyed, augmented, or created as the result of disposal of water.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Reptiles						
Milk snake	FS	Direct injury or mortality may occur to individuals during the project. Injury or mortality may occur as the result of disposal of water. Suitable habitats may be disturbed, destroyed, or fragmented during construction and production phases of the project.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Black Hills red-belly snake	FS	Not known to occur in Project Area.	No effect	No effect	No effect	No effect

BEST COPY AVAILABLE

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

Species Name	Listing Agency	Potential Effects	Population Determination			
			Alt. 1	Alt. 2A	Alt. 2B	Alt. 3
Fish						
Shovelnose sturgeon	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Lake chub	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from water disposal. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Plains minnow	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Sturgeon chub	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Flathead chub	FS, WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Mountain sucker	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]

BEST COPY AVAILABLE

731

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

			Population Determination			
Species Name	**Listing Agency**	**Potential Effects**	**Alt. 1**	**Alt. 2A**	**Alt. 2B**	**Alt. 3**
Black bullhead	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Yellowstone cutthroat trout	BLM, WGFD	No activities would occur in or upstream of occupied habitats within the Project Area.	No effect	No effect	No effect	No effect
Plains topminnow	FS, WGFD	Not known to occur in Project Area. Changes in water quality and quantity as the result of disposal of water may affect populations downstream of the Project Area.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Sauger	WGFD	No direct injury or mortality would be expected. Indirect injury or mortality, including effects to health or reproductive status, may occur resulting from disposal of water. Occupied habitats may be disturbed or destroyed by changes in water quality and quantity as the result of disposal of water. Disposal of water may augment or create new suitable habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Birds						
Common loon	FS, WGFD	No direct injury or mortality to adults would be expected from project activities. Injury or mortality to eggs or young may occur as a result of hydrologic changes during the nesting season. Individuals may be harassed or displaced during implementation of the project. Suitable aquatic nesting habitats would not be directly disturbed or destroyed during facility construction. Suitable aquatic nesting and foraging habitats may be disturbed, destroyed, augmented, or created as a result of changes in the hydrologic regime.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
American white pelican	WGFD	No direct injury or mortality to adults would be expected from the project. Injury or mortality to eggs or young may occur as a result of hydrologic changes during the nesting season. Individuals may be disturbed during implementation of the project. Suitable aquatic nesting habitats would not be directly disturbed or destroyed during facility construction. Suitable aquatic nesting and foraging habitats may be disturbed, destroyed, augmented, or created as a result of changes in the hydrologic regime.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
American bittern	FS, WGFD	No direct injury or mortality to adults would be expected from the project. Injury or mortality to eggs or young may occur as a result of hydrologic changes during the nesting season. Individuals may be harassed or displaced during implementation of the project. Suitable aquatic nesting habitats would not be directly disturbed or destroyed during facility construction. Suitable aquatic nesting and foraging habitats may be disturbed, destroyed, augmented, or created as a result of changes in the hydrologic regime.	May affect[A]	May affect[A]	May affect[A]	May affect[A]

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

			Population Determination			
Species Name	Listing Agency	Potential Effects	Alt. 1	Alt. 2A	Alt. 2B	Alt. 3
Black-crowned night heron	WGFD	No direct injury or mortality to adults would be expected from the project. Individuals may be harassed or displaced during implementation of the project. Nesting habitats would not be directly disturbed or destroyed by facility construction. Suitable aquatic nesting and foraging habitats may be disturbed, destroyed, augmented, or created as a result of changes in the hydrologic regime.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
White-faced ibis	FS, BLM, WGFD	No direct injury or mortality would be expected. Construction would not directly disturb aquatic habitats used during migration. Habitats used during migration may be disturbed, destroyed, augmented, or created as a result of changes to the hydrologic regime.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Trumpeter swan	BLM, WGFD	No direct injury or mortality to adults of this species would be expected. Injury or mortality to eggs or young may occur as a result of hydrologic changes during the nesting season. Individuals may be harassed or displaced by the project. Construction would not directly disturb aquatic habitats. Habitats used for nesting or migration may be disturbed, destroyed, augmented, or created as a result of changes to the hydrologic regime.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Osprey	FS	No direct injury or mortality would be expected as the result of the project. Collisions with aboveground utility lines, electrocution from contacting power lines, and vehicle collisions may result in injury or mortality. Harassment of nesting individuals would be minimized during the construction phase. Harassment or displacement of nesting individuals may occur during the production and abandonment phases of the project. Nesting habitats would not be physically disturbed or destroyed. Disposal of water and subsequent changes in water quality and quantity may disturb, destroy, augment, or create suitable foraging habitats.	May affect[b]	May affect[b]	May affect[b]	May affect[b]
Northern goshawk	BLM	No direct injury or mortality would be expected as a result of project activities. Collisions with aboveground utility lines, electrocution from contacting power lines, and vehicle collisions may result in injury or mortality. Harassment of nesting individuals caused by construction would be minimized. Harassment or displacement of nesting individuals may occur during the production and abandonment phases of the project. Nesting habitats would not be physically disturbed or destroyed. Direct disturbance would occur to habitats used by prey species. Disposal of water and resulting changes in water quality and quantity may disturb, destroy, augment, or create suitable foraging habitats.	May affect[b]	May affect[b]	May affect[b]	May affect[b]

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

			Population Determination			
Species Name	**Listing Agency**	**Potential Effects**	**Alt. 1**	**Alt. 2A**	**Alt. 2B**	**Alt. 3**
Ferruginous hawk	FS, BLM, WGFD	No direct injury or mortality would be expected as a result of project activities. Collisions with aboveground utility lines, electrocution from contacting power lines, and vehicle collisions may result in injury or mortality. Harassment of nesting individuals would be minimized during the construction phase. Harassment or displacement of nesting individuals may occur during the production and abandonment phases of the project. The project may disturb or displace foraging individuals. Unoccupied nesting habitats may be physically disturbed or destroyed. Direct disturbance would occur to habitats used by prey species. Disposal of water and resulting changes in water quality and quantity may disturb, destroy, augment, or create suitable foraging habitats.	May affect[B]	May affect[B]	May affect[B]	May affect[B]
Merlin	FS, WGFD	No direct injury or mortality would be expected as a result of project activities. Collisions with aboveground utility lines, electrocution from contacting power lines, and vehicle collisions may result in injury or mortality. Harassment of nesting individuals would be minimized during the construction phase. Harassment or displacement of nesting individuals may occur during the production and abandonment phases of the project. The project may disturb or displace foraging individuals. Unoccupied nesting habitats may be physically disturbed or destroyed. Direct disturbance would occur to habitats used by prey species. Disposal of water and resulting changes in water quality and quantity may disturb, destroy, augment, or create suitable foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Peregrine falcon	BLM, WGFD	Not known to nest within the Project Area. The project would not cause direct injury or mortality to migrating individuals. Disposal of water may disturb, destroy, augment, or create suitable foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Greater sandhill crane	BLM	No direct injury or mortality would be expected. No direct disturbance resulting from the project would occur to foraging habitats. Suitable foraging habitats may be disturbed, destroyed, augmented, or created as a result of methods of disposal for surface water.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Long-billed curlew	FS, BLM, WGFD	No direct injury or mortality to adults would be expected as a result of project activities. Nests may be disturbed or destroyed causing injury or mortality to eggs or young. Nesting or foraging individuals may be harassed or displaced by the project. Suitable nesting and foraging habitats may be disturbed, destroyed, or fragmented as a result of construction and disposal of water.	May affect[B]	May affect[B]	May affect[B]	May affect[B]
Upland sandpiper	FS	No direct injury or mortality to adults would be expected as a result of project activities. Nests may be disturbed or destroyed, causing injury or mortality to eggs or young. Nesting or foraging individuals may be harassed or displaced by the project. Suitable nesting and foraging habitats may be disturbed, destroyed, or fragmented as a result of construction and water disposal.	May affect[B]	May affect[B]	May affect[B]	May affect[B]

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

Species Name	Listing Agency	Potential Effects	Population Determination			
			Alt. 1	Alt. 2A	Alt. 2B	Alt. 3
Black tern	FS, WGFD	No direct injury or mortality to adults would be expected. Methods for disposal of water implemented during the nesting season may result in changes to habitat that cause injury or mortality to eggs and young. Nesting or foraging individuals may be harassed or displaced by the project. Suitable nesting and foraging habitats would be disturbed, destroyed, augment, or created.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Western yellow-billed cuckoo	FS, BLM, WGFD	No direct injury or mortality would be expected. Nesting and foraging individuals may be harassed or displaced by the project. Suitable nesting and foraging habitats may be affected as a result of changes to the hydrologic regime caused by water disposal.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Flammulated owl	FS	No activities would occur in occupied habitats within the Project Area.	No effect	No effect	No effect	No effect
Western burrowing owl	FS, BLM	No direct injury or mortality would be expected. Physical disturbance to nesting individuals would be minimized during the construction phase. Nesting and foraging individuals may be harassed or displaced by the project. Suitable and occupied nesting habitats would be disturbed, destroyed, or fragmented outside of the nesting season.	May affect[B]	May affect[B]	May affect[B]	May affect[B]
Lewis' woodpecker	FS, WGFD	No direct injury or mortality to adults would be expected. Injury or mortality may occur to eggs or young as a result of construction or water disposal. Nesting and foraging individuals may be harassed or displaced by the project. Disturbance, destruction, or fragmentation of nesting and foraging habitats would occur as a result of construction and disposal of water.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Olive-sided flycatcher	FS	Not expected to occur within the Project Area.	No effect	No effect	No effect	No effect
Loggerhead shrike	FS, BLM	No direct injury or mortality to adults would be expected. Injury or mortality may occur to eggs or young as a result of construction or disposal of water. Nesting and foraging individuals may be harassed or displaced by the project. Disturbance, destruction, or fragmentation of nesting and foraging habitats would occur as a result of construction and disposal of water.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Purple martin	FS	Not expected to occur within the Project Area.	No effect	No effect	No effect	No effect
Pygmy nuthatch	FS	No activities would occur in occupied habitats within the Project Area.	No effect	No effect	No effect	No effect
Sage thrasher	BLM	No direct injury or mortality to adults would be expected. Injury or mortality may occur to eggs or young as a result of construction or disposal of water. Nesting and foraging individuals may be harassed or displaced by the project. Disturbance, destruction, or fragmentation of nesting and foraging habitats would occur as a result of construction and water disposal.	May affect[A]	May affect[A]	May affect[A]	May affect[A]

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

			Population Determination			
Species Name	Listing Agency	Potential Effects	Alt. 1	Alt. 2A	Alt. 2B	Alt. 3
Brewer's sparrow	BLM	No direct injury or mortality to adults would be expected. Injury or mortality may occur to eggs or young as a result of construction or water disposal. Nesting and foraging individuals may be harassed or displaced by the project. Disturbance, destruction, or fragmentation of nesting and foraging habitats would occur as a result of construction and water disposal.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Sage sparrow	BLM	No direct injury or mortality to adults would be expected. Injury or mortality may occur to eggs or young as a result of construction or disposal of water. Nesting and foraging individuals may be harassed or displaced by the project. Disturbance, destruction, or fragmentation of nesting and foraging habitats would occur as a result of construction and disposal of water.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Baird's sparrow	FS, BLM	No direct injury or mortality to adults would be expected. Injury or mortality may occur to eggs or young as a result of construction or disposal of water. Nesting and foraging individuals may be harassed or displaced by the project. Disturbance, destruction, or fragmentation of nesting and foraging habitats would occur as a result of construction and disposal of water.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Fox sparrow	FS	No activities would occur in occupied habitats within the Project Area.	No effect	No effect	No effect	No effect
Mammals						
Little brown myotis	WGFD	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Long-eared myotis	BLM, WGFD	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Fringed-tailed myotis	FS	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Long-legged myotis	WGFD	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]

Table 4–57 Wyoming BLM, FS, and WGFD Sensitive Species Effects Evaluation

Species Name	Listing Agency	Potential Effects	Population Determination			
			Alt. 1	Alt. 2A	Alt. 2B	Alt. 3
Western small-footed myotis	WGFD	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Big brown bat	WGFD	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Spotted bat	BLM	Not expected to occur within the Project Area.	No effect	No effect	No effect	No effect
Townsend's big eared bat	FS, BLM, WGFD	No direct injury or mortality would be expected. Foraging individuals may be harassed or displaced by the project. Foraging habitats may be disturbed, destroyed, or fragmented by the project. Methods for disposal of water may augment or create foraging habitats.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
Swift fox	FS, BLM, WGFD	Direct injury or mortality may occur to individuals. Individuals may be harassed or displaced by the project. Suitable hunting and denning habitats would be disturbed, destroyed, or fragmented.	May affect[A]	May affect[A]	May affect[A]	May affect[A]
White-tailed prairie dog	BLM	Not known to occur within the Project Area.	No effect	No effect	No effect	No effect

Notes:

A May adversely affect individuals, but not likely to result in a loss of viability on federal lands or range wide or result in a trend toward federal listing.

B May adversely affect individuals, may result in a loss of viability on federal lands or range wide, or result in a trend toward federal listing.

Vehicle Collision

Few studies have specifically examined effects of collision on upland game; however, this impact probably would be limited because grouse tend to flush only when closely approached and then fly close to the ground and at a relatively high speed. The literature on avian mortality caused by collision with vehicles is reviewed by Erickson et al. (2001). The new roads could result in a potential increase in vehicle collisions with sage grouse. However, the effect of a limited increase in the potential for vehicle collisions on the population of sage grouse would be minimal and limted to areas of concentrated development that are occupied by this species.

Power Line Collision

Relatively few comprehensive studies have been conducted, and nationwide annual estimates of avian mortality caused by collision with power lines vary greatly. The literature on avian mortality caused by collision with power lines is reviewed by Erickson et al. (2001). Although construction of new power lines may increase the potential for collision, measurable mortality due to sage grouse colliding with conductors is not expected because the birds fly close to the ground below the typical height of power lines.

Fences

Fences, which are common throughout the Project Area, are hazardous to sage grouse because they can result in mortality caused by collision (Connelly et al. 2000). New barbed wire fences would be constructed, primarily to keep wildlife and livestock out of construction, production, and water handling areas. These fences would enclose a relatively small area. New fences would be constructed to meet BLM guidelines designed to reduce the potential for wildlife entanglement. New fences that cross large areas would not be constructed. Construction of fences would have minimal effects on sage grouse because of the relatively short lengths that would be built.

Predation by Raptors

New power lines could affect sage grouse, especially near lek complexes, if they provide new perches for raptors, which could result in increased predation (Oedekoven 2001). Sage grouse tend to avoid areas associated with power lines, resulting in the indirect loss of habitats near these structures (WGFD 2002). Lek sites with power lines located less than 0.25 mile away have shown reduced attendance compared with sites where power lines are not as close (Braun et al. in press). Avoidance of otherwise suitable habitats within 0.5 mile of power lines by sage grouse also has been documented (San Miguel Basin Sage Grouse Working Group 1998). Locating power lines away from leks and raptor-proofing the poles for aboveground power lines constructed within 0.5 mile of leks would reduce the potential for increased predation on sage grouse at leks. Still, grouse that use other seasonal habitats away from lek sites may experience increased raptor predation and may reduce their use of otherwise suitable habitats near power lines. Although some additional predation by raptors may occur, this predation is not expected to substantially affect the population of sage grouse in the PRB, especially if the poles for aboveground power lines and are raptor-proofed and located away from leks.

735

Loss or Degradation of Habitats

The project would result in the direct disturbance of sage grouse habitats. Direct habitat loss and degradation have been implicated in the decline in lek attendance and abandonment for sites where oil and gas development has occurred within 0.25 mile (Braun et al. in press). Table 4–58 shows the predicted proportion of known leks where project-related facilities would be located within 0.25 mile. Data on lek locations would be reviewed before surface disturbance begins to avoid direct disturbance to leks. Surveys would be conducted within suitable grouse habitats to locate leks that may be disturbed. No surface occupancy would be allowed within 0.25 mile of a lek to avoid direct disturbance. This stipulateon is attached to oil and gas leases and is nondiscretionary. Therefore, it applies to federal oil and gas leases, regardless of surface ownership. Disturbance would occur to all other habitat types, including nesting, brood rearing, and wintering areas that are located more than 0.25 mile from lek sites.

Table 4–58 Proposed and Cumulative Impacts to Sage Grouse Protective Buffers by Sub-watershed — Alternatives 1, 2A, and 2B

Sub-watershed	Proportion of leks with oil and gas development within the specified buffer			
	Proposed		Cumulative	
	0.25-mile buffer (percent)	2.0-mile buffer (percent)	0.25-mile buffer (percent)	2.0-mile buffer (percent)
Little Bighorn River	0.0	0.0	0.0	0.0
Upper Tongue River	0.0	42.9	7.1	50.0
Middle Fork Powder River	0.0	53.8	0.0	53.8
North Fork Powder River	0.0	0.0	0.0	0.0
Upper Powder River	22.7	97.7	34.1	97.7
South Fork Powder River	0.0	20.0	0.0	20.0
Salt Creek	0.0	80.0	20.0	100.0
Crazy Woman Creek	5.3	89.5	5.3	89.5
Clear Creek	27.3	100.0	27.3	100.0
Middle Powder River	50.0	100.0	100.0	100.0
Little Powder River	35.7	100.0	53.6	100.0
Little Missouri River	0.0	0.0	0.0	0.0
Antelope Creek	9.1	90.9	18.2	100.0
Dry Fork Cheyenne River	10.0	75.0	15.0	95.0
Upper Cheyenne River	0.0	62.5	12.5	100.0
Lightning Creek	0.0	66.7	16.7	83.3
Upper Belle Fourche River	20.0	86.7	46.7	97.8
Middle North Platte River	0.0	61.5	7.7	76.9
Project Area	14.9	80.7	26.9	88.0

Most nests are close to leks (Braun [illegible] 1977) and hens show strong site fidelity, which may be in response to the presence of important vegetative nesting habitat characteristics such as sagebrush, forb and grass cover, and height of sagebrush (Lyon 2000). Hens from disturbed leks adapt in part by selecting higher canopy cover and shrub height in sagebrush (Lyon 2000), a resource that would be increasingly limited in the Project Area. The proposed development could disturb suitable and potentially suitable habitats for sage grouse. Short-term disturbance to sagebrush shrublands would encompass 53,626 acres within the Project Area. This disturbance accounts for 2 percent of the available sagebrush vegetation type within the Project Area (2,234,103 acres). Disturbances to riparian areas and wet meadows that provide an important component of brood-rearing habitats would be minimal because of the mitigation measures designed to limit disturbance in riparian areas.

Loss of habitat associated with construction would have negative effects on sage grouse if the habitats are occupied by the grouse, particularly during the breeding season. Return to pre-disturbance levels of population during the production phase is not expected if habitats occupied by the grouse are disturbed. Natural recruitment of sagebrush may occur over time. Sage grouse habitats would not be restored to pre-disturbance conditions for an extended period because of the time needed to develop sagebrush stands with characteristics that are preferred by sage grouse.

Water Handling

Disposal of produced water may benefit sage grouse (Oedekoven 2001). Hens with broods, barren hens, and roosters preferentially use wet meadows and riparian areas during the summer and show strong site fidelity (Lyon 2000). Produced water from surface discharge may expand existing wetland and riparian areas and create new wetland and riparian habitats. These expanded and new habitats would provide additional brood rearing and summering habitats for sage grouse. Water impoundments and increased water flows would also provide additional sources of drinking water for sage grouse.

Water-handling methods could also have negative effects on sage grouse. The construction of water handling facilities, such as containment impoundments, could result in the loss of sagebrush shrublands that are used as nesting and other seasonal habitats by this species, despite a mitigation measure that requires avoidance of sagebrush shrublands where possible. A total of 27,009 acres would be disturbed by construction of the various water handling facilities. The higher water table associated with surface discharge would kill sagebrush, which is not tolerant of saturated root zones. Additional losses of sagebrush may occur from the LAD method for disposing of production water for the same reason. A summary of losses by habitat type, including contributions from water handling methods, is presented in the section on Vegetation of this chapter.

Harassment, Displacement, and Noise

Human disturbance, including construction, road use, and noise from project facilities, may result in adverse effects to sage grouse, particularly during the breeding season (Braun et al. in press). Disturbance during the breeding period may result in reduced breeding activity (Lyon 2000). Nest initiation rates have been shown to be lower for hens from disturbed leks compared with undisturbed leks, although nest success was similar (Lyon 2000).

Sage grouse nest farther from disturbed leks (2.6 miles) than from undisturbed leks (1.3 miles) (Lyon 2000). Table 4-64 shows the predicted proportion of known lek sites where project-related facilities would be located within 2 miles.

240

BEST COPY AVAILABLE

Mitigation measures would prevent new surface disturbance within 2 miles of leks on federal leases during the breeding period, reducing disturbance to sites and nests. Nests located farther than 2 miles from leks may be disturbed during the project.

Regular traffic along roads, as would be experienced during the production phase, can affect lek activity and reduce survival (Braun et al. in press). Activity along roads may cause nearby leks to become inactive over time (WGFD 2002). Sage grouse do not appear to avoid roads, but shift their habitat use when nesting near roads to patches of sagebrush with higher canopy cover and height (Lyon 2000). Sagebrush stands that meet these requirements may be limited, especially in areas of concentrated development, resulting in decreased nesting success. The limitation on new disturbance within 2 miles of leks during the breeding season would not apply to production or to new disturbance on private lands. Production in nesting habitats may result in substantial adverse impacts to breeding sage grouse.

Noise can affect sage grouse by preventing vocalizations that influence reproductive and other behaviors (WGFD 2002). Sage grouse attendance on leks within 1 mile of compressors is lower than for sites farther from compressor locations (Braun et al. in press). A lease stipulation addresses the effects of noise from compressors on leks, prohibiting new compressors within 0.5 mile of leks and limiting the increase in noise to levels less than 49 dBA. This stipulation is attached to oil and gas leases and is nondiscretionary. Therefore, it applies to federal oil and gas leases, regardless of surface ownership.

Each of these indirect effects has the potential to cause impacts to individual sage grouse and entire populations. The mitigation measures that have been developed would reduce these impacts to some extent; however, the potential remains for impacts and decreasing sage grouse populations to occur as a result of the proposed project.

Habitat Fragmentation

Sage grouse habitat can be fragmented by roads, power lines, fences, and reservoirs (Connelly et al. 2000). Habitat fragmentation associated with oil and gas development may affect sage grouse use of leks, nesting habitats, and early brood-rearing habitats (Lyon 2000). Sage grouse continue to use sites fragmented by linear facilities, provided that sufficient sagebrush habitats remain available and that some areas are visually and audibly isolated from physical structures (fences, aboveground power lines) and actively used roads (Braun et al. in press).

Sage grouse have been documented to move in excess of 45 miles between seasonal ranges in migratory populations (Connelly et al. 1988). During these migrations, they can cross highways, roads, agricultural fields, and other areas of nonnative habitats. The level of fragmentation that would occur under the proposed project would not substantially fragment habitats used by sage grouse and is not expected to affect patterns of seasonal movements on a landscape scale.

One potential effect of the large extent of new roads that would fragment sage grouse habitats would be an increase in the number of fires caused by humans.

Fire results in decreased sagebrush cover and subsequent declines in sage grouse populations in burned areas (Connelly et al. 2000).

Increased predation associated with poor-quality or fragmented habitats can result in reduced reproductive success, although declines in population are not often associated with high levels of predation (Connelly et al. 2000). Habitats with low grass and shrub cover do not provide the concealment needed to avoid nest predation (Gregg et al. 1994, DeLong et al. 1995). Construction of roads, power lines, pipelines, and other facilities would result in decreased cover and may result in increased nest predation.

Early brood rearing appears to be the most limiting life stage for sage grouse (Lyon 2000). Use of early brood rearing habitat is concentrated in areas with high forb cover, which correlates with high insect availability, an important food for young chicks (Lyon 2000). Invasion by noxious weeds (see the section on Vegetation) would result in decreased forb productivity, which may affect the quality of early brood rearing habitat. Chick survival during this critical period could be reduced in areas of extensive weed invasion because of decreased food resources and increased predation associated with the need for chicks to travel farther to find adequate food.

Population Effects

Vehicle and power line collisions, increased raptor predation, habitat loss, displacement, noise, and habitat fragmentation all have the potential for substantial negative effects on sage grouse populations, despite any potential benefits that would be derived from increased availability of water (Oedekoven 2001). Implementation of several mitigation measures would reduce the extent of each impact addressed by those measures. Despite these measures, the synergistic effect of several impacts would likely result in a downward trend for the sage grouse population, and may contribute to the array of cumulative effectgs that may lead to its federal listing. Local populations may be extirpated in areas of concentrated development, but viability across the Project Area or the entire range of the species is not likely to be compromised.

Alternative 2A

Under Alternative 2A, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed facilities for water handling. Alternatives 2A and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 36,263 acres would be disturbed by water handling facilities under this alternative (Table 2–23), an increase of 34 percent over the disturbance from water handling associated with Alternative 1; therefore, a similar increase in effects from water handling is expected. This change may result in increased beneficial effects; however, the extent of negative impacts associated with other aspects of the project as discussed under Alternative 1 would continue to represent an overall negative effect on sage grouse populations.

Alternative 2B

Under Alternative 2B, the magnitude and types of effects would be similar to those presented for Alternative 1, with the exception of the effects associated with proposed water handling facilities. Alternatives 2B and 1 differ only in the proportion of the various water handling methods and their associated disturbances. The types of effects associated with water handling methods are discussed under Alternative 1. Approximately 32,653 acres would be disturbed by water handling facilities under this alternative, an increase of 21 percent over the disturbance from water handling associated with Alternative 1; therefore, a similar increase in effects from water handling is expected. This change may result in increased beneficial effects; however, the extent of negative impacts associated with other project activities, as discussed under Alternative 1, would continue to represent an overall negative effect on the sage grouse population.

Alternative 3

Under Alternative 3, the types of effects to sage grouse would be similar to those presented for Alternative 1. The magnitude of these effects would be substantially smaller, however. Alternative 3 would result in the disturbance of 35 percent of the amount of habitat (Table 2–32) that would be affected under Alternatives 1, 2A, and 2B, because the total number of new wells would be reduced to 40 percent (Table 2–29). Table 4–59 shows the predicted proportion of known sage grouse lek sites where project-related facilities would be located within 0.25 and 2.0 miles. The effects from water handling would be essentially the same as were discussed for Alternative 1; however, the magnitude of these effects would be smaller. Approximately 11,683 acres would be disturbed by water handling facilities under this alternative (Table 2–32), a decrease of 57 percent from the disturbance associated with Alternative 1. The reduction in impacts from the project, including water handling facilities, would result in reduced impacts to sage grouse. Despite this reduction, the large scale and widespread nature of the anticipated impacts, particularly in terms of vehicle and power line collisions, increased raptor predation, habitat loss, displacement, noise, and habitat fragmentation, suggest that declines in the sage grouse population may occur. The degree of this potential decline is not known, although it would be smaller than under the other three alternatives. Local populations may be extirpated in areas of concentrated development, but viability across the Project Area or the entire range of the species is not likely to be compromised.

Cumulative Effects

Implementation of each of the alternatives would contribute to cumulative effects to sage grouse that occur within the Project Area. Table 4–58 and Table 4–59 show the predicted cumulative proportion of known lek sites where oil and gas facilities would be located within 0.25 and 2.0 miles. The cumulative effects to sage grouse from current, proposed and future activities such as gas and mineral exploration and development, agriculture, and urban development may include increased mortality, especially from collisions with vehicles and power lines and increased raptor predation; displacement and harassment; physical degradation or destruction of breeding grounds (leks) and reproductive areas (nesting and brood-rearing areas), and habitat fragmentation. Surface coal mining and sagebrush treatment have reduced the availability of sagebrush habitats in the Project Area (Oedekoven 2001). Conversion of native habitats to agriculture has decreased in recent years, but has decreased availability of sage grouse habitats. This impact is likely reflected in the long-term downward trend in the sage grouse population in the Project Area (Oedekoven 2001). Livestock grazing has been implicated as one factor in the cumulative loss and degradation of sage grouse habitats (WGFD 2002). Livestock grazing occurs throughout the Project Area.

Table 4–59 Proposed and Cumulative Impacts to Sage Grouse Protective Buffers by Sub-watershed — Alternative 3

	Proportion of leks with oil and gas development within the specified buffer			
	Proposed		Cumulative	
Sub-watershed	0.25-mile buffer (percent)	2.0-mile buffer (percent)	0.25-mile buffer (percent)	2.0-mile buffer (percent)
Little Bighorn River	0.0	0.0	0.0	0.0
Upper Tongue River	0.0	35.7	7.1	42.9
Middle Fork Powder River	0.0	30.8	0.0	30.8
North Fork Powder River	0.0	0.0	0.0	0.0
Upper Powder River	18.2	97.7	29.5	97.7
South Fork Powder River	0.0	20.0	0.0	20.0
Salt Creek	0.0	0.0	0.0	20.0
Crazy Woman Creek	5.3	89.5	5.3	89.5
Clear Creek	27.3	90.9	27.3	90.9
Middle Powder River	50.0	100.0	50.0	100.0
Little Powder River	21.4	89.3	39.3	92.9
Little Missouri River	0.0	0.0	0.0	0.0
Antelope Creek	9.1	63.6	18.2	72.7
Dry Fork Cheyenne River	0.0	35.0	0.0	90.0
Upper Cheyenne River	0.0	62.5	0.0	87.5
Lightning Creek	0.0	16.7	16.7	66.7
Upper Belle Fourche River	13.3	82.2	35.6	88.9
Middle North Platte River	0.0	30.8	7.7	61.5
Project Area	10.4	67.9	20.1	78.7

The total acreage affected by CBM development would not be disturbed simultaneously because it would occur over the life of the project. Some of the disturbed acreage would be reclaimed or would be in the process of being reclaimed when new disturbances are initiated. CBM development is expected to occur at a rate faster than abandonment and reclamation of wells. In the near future, the amount of disturbed habitats is likely to increase, although the anticipated life of CBM wells indicates that reclamation would eventually overtake development of new wells, resulting in a net decrease in disturbed vegetation for the long term. In areas reclaimed after CBM development, vegetation often differs substantially from undisturbed areas, as discussed in the section on Vegetation. Reclamation of sagebrush and other habitats important to sage grouse may take many years to complete (WGFD 2002). As a result, shifts in the composition or distribution of habitat would affect sage grouse within the Project Area.

244

USFWS may consider the cumulative effects of the proposed project in its response to two petitions that seek listing of the sage grouse under the Endangered Species Act in portions of its range that include the Project Area. The findings on these petitions are not yet known (Diebert 2002). The sage grouse population in Wyoming, although reduced from historical levels, is still among the healthiest in the range of the species (Lyon 2000). The prediction of declines in population over a large part of the state that contains the healthiest populations of sage grouse may result in increased scrutiny of population across the range of this species and may lead, either directly or indirectly, to listing under the ESA.

Implementation of any of the alternatives would contribute to cumulative adverse effects to the threatened, endangered, proposed, candidate, and sensitive species in the Project Area. Cumulative short- and long-term disturbances to these species are many and stem from several sources. Included in the cumulative effects evaluated are the direct effects of oil and gas (CBM and non-CBM) extraction, as well as development of new oil and gas wells on adjacent lands. Oil and gas development would occur on a mix of federal, state, private, and split estate lands. Additional oil and gas extraction (CBM and non-CBM) may occur later within the Project Area beyond the level of development currently considered. Activities other than oil and gas extraction that contribute to cumulative effects in the Project Area include: coal mining; uranium mining; sand, gravel, and scoria mining; ranching; agriculture; construction of roads and railroads; and development of rural and urban housing. The effects of these activities on vegetation and wildlife resources are discussed in detail in the sections on Vegetation and Wildlife, above.

Cultural Resources

The goal of the consideration of historic properties under Section 106 of the National Historic Preservation Act of 1966 as amended (P.L. 89–665; P.L. 95–515; P.L. 102–575; 80 Stat. 915; 16 USC 470), its implementing regulations, including but not limited to 36 CFR §800, 36 CFR §61, and Executive Order 11593, NEPA (P.L. 91–190; 83 Stat. 852; 42 U.S.C. 1500–17.7; 42 U.S.C. 4321–61) and its implementing regulations including 40 CFR §1500–1508, is the preservation of the cultural values embodied in those historic properties. The BLM national cultural resource management objectives to meet the requirements of the latter statutory authorities and additional related authorities listed in BLM Manual M-8100.03 are:

A. Respond in a legally and professionally adequate manner to (1) the statutory authorities concerning historic preservation and cultural resource protection, and (2) the principles of multiple use.

B. Recognize the potential public and scientific uses of, and the values attributed to, cultural resources on the public lands, and manage the lands and cultural resources so that these uses and values are not diminished, but rather are maintained and enhanced.

C. Contribute to land use planning and the multiple use management of the public lands in ways that make optimum use of the thousands of years of land

245

use history inherent in cultural resource information, and that safeguard opportunities for attaining appropriate uses of cultural resources.

D. Protect and preserve in place representative examples of the full array of cultural resources on public lands for the benefit of scientific and public use by present and future generations.

E. Ensure that proposed land uses, initiated or authorized by BLM, avoid inadvertent damage to federal and non-federal cultural resources.

The operational objectives to achieve this goal are:

1. Identification of historic properties within the area of potential effect of proposed actions that are part of or associated with the federal undertaking;
2. Evaluation of the cultural values of those historic properties within appropriate historic contexts; and
3. Avoidance or minimization of adverse effects to those cultural values.

The cultural resources management objective of the BLM Buffalo Field Office, including stewardship considerations in addition to Section 106 and NEPA compliance is to "Protect, preserve, interpret, and manage significant cultural resources for their informational, educational, scientific, and recreational values" (BLM 2001:4). However, in cases of split estate, surface resources, such as cultural sites, belong to the surface owner. The surface owner must be consulted about investigation, mitigation, or monitoring.

These objectives are achieved through:

1. Inventory;
2. Evaluation;
3. Native American Consultation;
4. Management Options; and
5. Monitoring

Inventory is the process of gathering together information on the cultural resources that are present in the area of a proposed undertaking. Levels of inventory include an overview that reviews documentation of previously known resources and intensive pedestrian survey that inspects the area of potential effect (APE) for all evidence of previously known and undocumented cultural resources. Site-specific inventories are required before surface disturbing activities for all federal actions that involve federal surface, federal minerals, federal funding, or federal permits. Cultural resource surveys are conducted for individual wells, well fields, or PODs as part of the APD process. Block surveys at the well field or POD level are advantageous for planning, management, and development and eliminate the need for many follow-up or in-fill surveys. Cultural resource inventories must conform to current Wyoming standards and guidelines, including the BLM Handbook H–8111–1 Cultural Resources Wyoming Handbook, guidance for completion of the Wyoming Cultural Properties Form, and the Buffalo BLM CBM Guidebook.

BEST COPY AVAILABLE

246

Evaluation is the process of assessing the importance of a cultural resource site. All cultural resource sites and many Native American traditional places are evaluated in accordance with the National Register Criteria (36 CFR 60.4 (a-d)) and within a defined historic context. The National Register Criteria assess whether a site is eligible for listing on the National Register of Historic Places at the national, state, or local level. A site that is listed on or is eligible for the National Register of Historic Places is considered a historic property. Typically, the majority of cultural resource sites are evaluated as not eligible. Cultural resources are evaluated as completely as possible during initial documentation. If a site cannot be conclusively evaluated from surface evidence and limited testing, the additional information or specialized analysis necessary to complete the evaluation are identified and a recommendation is made for the most prudent and expedient procedure to complete the evaluation. Additional studies might include archival or other documentary research, evaluation of the resource by a specialist, analysis of specialized samples, subsurface test excavations, or other forms of well-defined research that are beyond the scope of surface survey.

BLM or FS will contact tribes that may have legitimate concerns within or related to proposed undertakings and convey the major findings of cultural resource inventories. The tribes may raise concerns about the treatment of cultural resources, natural resources, or natural landscape features that have traditional religious or cultural value. These groups also have concerns about handling inadvertent discoveries of human remains. (The plan for handling human remains in the PRB is provided in Appendix L.) Consultation is the government-to-government identification of concerns and discussion of their resolution.

Management options are standard treatments of historic properties, Native American concerns, or inadvertent discoveries. The preferred option for the treatment of historic properties is avoidance and protection. In most cases, the historic property can be avoided and protected by minor adjustments or stipulations to the proposed undertaking, especially if an adequate area has been surveyed for cultural resources. If a historic property cannot feasibly be avoided, data recovery or other mitigation measures are proposed. The nature and level of mitigation depend on the nature and extent of the adverse effect to the historic property and must be approved by the BLM or FS, in consultation with the SHPO and, if applicable, the surface owner. Any data recovery plan must discuss the property in terms of the historic context and identify the research questions that would be addressed by the anticipated data classes.

Monitoring is conducted to: (1) verify that actions have complied with constraints and stipulations; (2) verify that the constraints and stipulations have achieved the intended objectives; and (3) evaluate whither management plans and objectives have achieved their goals. Monitoring includes monitoring construction for compliance, monitoring for potential discovery situations, and monitoring of ongoing operations.

Inventory and Evaluation

Cultural resource sites are defined as discrete locations of past human activity, which can include artifacts, structures, works of art, landscape modifications, and

241

natural features or resources important to history or cultural tradition. These sites can include extensive cultural landscapes (for example, farm or ranch landscapes), linear landscapes (for example, historic trails with associated towns, forts, and way stations), or railroad landscapes and traditional use areas. In this document, significant sites are defined as those sites that are listed on, determined eligible for, or recommended eligible for the National Register of Historic Places under the Criteria for Evaluation (36 CFR § 60.4), and sites that have not been evaluated.

Federal regulations require cultural resource inventory, recordation, and evaluation of resources in the area of potential effect as part of the approval process. Archaeological clearance is required by the Section 106 process prior to disturbance for all federal undertakings, including projects on federal surface, projects recovering federal minerals, and all project requiring federal funding or permits. All areas of proposed ground disturbing activity must be inventoried for cultural resources. Any discovered resources must be documented and evaluated for eligibility for the NRHP. In most cases and with proper planning, effects to eligible properties can be minimized. Indirect effects from changes to soil stability or drainage patterns cannot always be anticipated. Indirect effects can be minimized by soil stabilization, fencing, or protective barriers to prevent inadvertent traffic in sensitive areas. Direct and indirect effects when eligible sites cannot be avoided would be subject to mitigation procedures. Adverse effects can be minimized by implementation of approved data recovery plans. There are a large number of unevaluated sites. These sites can be avoided or additional studies can be implemented to evaluate them. In addition, specific procedures are established for the treatment of unanticipated discoveries and human remains that were not identified by surface investigation.

An important element of the inventory and evaluation process is the evaluation of previously known and newly discovered cultural resources and an assessment of potential effects. The following list represents the potential sequence in the evaluation of a cultural resource.

- A cultural resource is identified and documented or revisited.
- The resource does not meet any of the National Register Criteria. If the resource is evaluated as not eligible, no further work is required beyond the documentation of the site and its evaluation. Generally, the majority of cultural resources are evaluated as not eligible.
- Information available from surface survey and limited testing is inadequate to evaluate the resource. Additional historic documentation, specialized analysis, or subsurface testing is necessary to complete evaluation. If, after this additional work, the resource is evaluated as not eligible, no further work is required.
- The resource meets one or more of the National Register Criteria and is identified as a historic property.
- Assessment of the potential effects of the proposed actions indicates that the historic property will not be affected or that the proposed actions can be modified to avoid any adverse effects.

248

- Assessment of the potential effects of the proposed actions indicates that portions of the historic property may be affected, but that those portions of the historic property do not contribute to the eligibility of the historic property. Constraints are identified to protect the contributing portions of the historic property from adverse effects.
- If adverse effects to the historic property cannot feasibly be avoided, a treatment is recommended to minimize or mitigate adverse effects.

Native American Consultation

Effects to traditional cultural properties, localities of traditional concern, and sacred sites must be considered. Federal regulations require consultation with recognized Native American tribes. These include, but are not limited to:

National Historic Preservation Act, as amended (P.L. 89–665; P.L. 95–515; P.L. 102–575; 80 Stat. 915; 16 U.S.C. 470–470t; 36 CFR §60; 36 CFR §65; 36 CFR §800; 36 CFR §801; 36 CFR §61; Executive Order 11593). This act requires federal agencies to consult with Indian tribes regarding federal undertakings in order to identify properties with tribal religious or cultural significance that may be eligible for the National Register of Historic Places (Traditional Cultural Places), and to determine ways to avoid or minimize effects to those properties.

National Environmental Policy Act (P.L. 91–190; 83 Stat. 852; 40 U.S.C. 1500–17.7; 42 U.S.C. 4321–61; 43 CFR 1500–1508). This act requires federal agencies to consult with Native American tribes regarding land use plans.

Federal Land Policy and Management Act (PL 94–579; 90 Stat. 2743; 43 U.S.C. 1701). This act provides Native American tribes and groups the opportunity to express their views and identify places of concern.

American Indian Religious Freedom Act (P.L. 95–431; 92 Stat. 469; 42 USC 1996 and 1996a; 43 CFR §7; Executive Order 13007). This act requires federal land managing agencies to identify, through consultation, the concerns of traditional Native American religious practitioners, and to accommodate access to and ceremonial use of sacred sites in the planning process.

Archaeological Resources Protection Act (P.L. 96–95; 93 Stat. 721; 16 U.S.C 470aa–470mm; P.L. 100–555; P.L. 100–588). This act requires consideration of Native American concerns and requires that federal land managing agencies notify appropriate tribes before approving permits for excavation of archaeological resources if the location may have cultural or religious importance to the tribes.

Native American Graves Protection and Repatriation Act (P.L. 101–601; 104 Stat. 3048; 25 U.S.C. 3001; 43 CFR §10). This act requires federal agencies to consult with appropriate tribes before the authorization of excavation or removal of Native American human remains and funerary objects

BEST COPY AVAILABLE

with the purpose of determining how the tribes would like the agency to treat these remains.

Executive Order No. 13007 Indian Sacred Sites. This order requires federal agencies to accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners, to avoid adversely affecting the physical integrity, and to maintain the confidentiality of sacred sites.

In carrying out its mandated responsibilities, BLM is obligated to ensure that the concerns that Native Americans have about federal land use plans are adequately addressed. BLM must foster and maintain credible government-to-government relationships with Native American tribes.

BLM has identified more than 26 tribes that may have traditional interests and concerns in the planning area. These include, but are not limited to, the Kiowa Tribe, the Apache Tribe, the Comanche Tribe, various Lakota bands and tribes, the Northern Arapaho Tribe, the Northern Cheyenne Tribe, the Crow Tribe, the Eastern Shoshone Tribe, the Turtle Mountain Chippewa, and the Three Affiliated Tribes (Mandan, Hidatsa, and Arikara). In the first quarter of 2001 and again in the first quarter of 2002, letters inviting participation in the NEPA analysis were sent to all of the tribes and bands that were identified regarding the PRB Oil and Gas EIS. Follow-up letters were again sent to all the above tribes seeking participation. In April 2002, additional letters were sent to the Chairmen of the Crow Tribe and the Northern Cheyenne Tribe. Responses expressing concerns were received from the Kiowa Tribe, the Apache Tribe, the Comanche Tribe, the Teton Lakota Tribe, the Oglala Lakota Tribe, and bands of the Minneconjou, Siha Sapa, Oohenumpa and Itazipco Lakota. Meetings were held with Cheyenne River and Oglala Sioux in April 2001; May 2001 with the Kiowa, Comanche, and Apache; March 2002 with the Oglala, Cheyenne River and Rosebud Sioux; and in April 2002 additional letters to Chairman of Crow and Northern Cheyenne were sent. Concerns were raised about sacred sites, protocols related to unearthing of human remains, water quality in the Cheyenne River and participation in the development by tribal members as project monitors.

Treatments

Adverse effects to cultural resources can result from the construction and operation of well pads, access roads, pipelines, power lines, and compressor stations, and from vehicular travel. Effects to sites can be direct as a result of construction or other earth disturbing activities, or can be indirect as a function of such things as increased erosion, increased access, vibration from traffic or machinery, or alteration of the setting. Adverse affects to cultural properties may include alteration of visual, atmospheric, and auditory aspects of site setting, or site destruction by placement of facilities and infrastructure. Indirect effects can be particularly important in the consideration of sites that are eligible for their location, setting, and feeling, such as emigrant trails or locations of historic battles. Cultural sites are a nonrenewable resource and, if disturbed, lose potential information, integrity, and heritage value. Avoidance of eligible sites is the preferred mitigation. Although careful project planning can help alleviate inadvertent or unintentional effects to eligible sites, such effects can still occur. Data recovery plans can be

256

undertaken in cases where eligible sites cannot be avoided or are unintentionally affected. Mitigation of adverse impacts may include, site avoidance through project relocation or redesign, visual resource management including adjustment of the color of facilities, landform screening, detailed mapping and recordation, historic documentation, or data recovery.

Many areas of federal minerals in the Project Area are privately owned surface. The surface owners must be kept informed of activities that are planned on their property, including the identification and treatment of historic and prehistoric resources. They must also understand, or be reassured that resources on their property belong to them, that they will be consulted in the mitigation process, and that they will have the option of taking possession of any cultural materials recovered on their land after the completion of appropriate documentation and analysis. BLM's responsibility is to consider its effects to historic properties. Where necessary and possible, BLM, in consultation with SHPO and the applicant, will address mitigation of adverse impacts to historic properties. Pursuant to the State Protocol Agreement between the Wyoming BLM State Director and the Wyoming State Historic Preservation Officer, BLM may consider, in consultation with the SHPO, proceeding with the action with an adverse effect to historic properties, applying the Criteria of Adverse Effect (36 CFR Part 800.9(b)). This option is pursued when treatment efforts will not be able to mitigate impacts or mitigation is infeasible, is not appropriate, or is not cost effective. Table 4–60 briefly outlines typical effects to historic properties and options for dealing with those effects.

Project Alternatives

The Project Area has been divided into 18 sub-watersheds for this analysis. The total square miles, square miles surveyed, percent surveyed, and average sites per square mile by watershed are shown in Table 4–61. The amount of land involved varies greatly by watershed, with the largest amount of acreage in the Upper Powder River watershed and the smallest in the North Fork Powder River. As expected, the surveyed areas and percent of area surveyed also varied greatly. Figure 4–44 shows sections in the Project Area that have been surveyed intensively and the relative density of sites recorded. The average percent of area surveyed for the total Project Area is 10.2 percent with a high of 40.6 and a low of 0.7 percent. The number of sites per square mile for the total Project Area is 6.1, with the largest number of sites per square mile found in the Clear Creek sub-watershed and the smallest in the Upper Belle Fourche River sub-watershed. The Clear Creek sub-watershed is a diverse area that is likely to have a high density of sites. However, in this table, the site density is also inflated by thematic surveys that reported sites, but where no survey acreage is associated. The total number of sites recorded in all the watersheds appears low but is likely a result of the amount of surveyed acreage being low rather than indicating a low site density. The most common sites in the Project Area are prehistoric artifact scatters and rural historic sites.

Table 4–60 Typical Treatment Options for Historic Properties

Potential Impacts	Property Types	Treatment Measures
Physical destruction of the property, or elements of the property by construction, operation, or associated activities	All property types	Avoidance and protection of property.
		Avoidance and protection of contributing or sensitive portions of the property. Activities can occur in non-contributing areas.
		If the property cannot be avoided, an approved plan for recordation, relocation, or data recovery (mitigation) may be implemented.
Indirect deterioration of property caused by destabilization of the structure itself or of associated sediments or bedrock, damage by fumes or dust, or alteration of vegetation.	Buildings, standing structures, rock art or non-portable art, or buried sites, including bone beds.	Avoidance and protection that may include control of potential erosion, sedimentation, or destabilization by limitation of activities near the property, stabilization measures, or erosion control.
		Control measures to minimize damage to native vegetation and prevent invasion by aggressive weeds.
		Control measures, including designated buffer distances and protective barriers, to minimize effects of vibration, dust, or fumes.
		Rehabilitation of buildings or structures to minimize potential deterioration.
		If deterioration cannot be avoided, an approved plan for recordation, relocation, or data recovery (mitigation) may be implemented.

BEST COPY AVAILABLE

252

Table 4-60 Typical Treatment Options for Historic Properties

Potential Impacts	Property Types	Treatment Measures
Visual or auditory intrusion on the historic setting of a property that is important for its location and setting.	May include certain buildings, structures, and locations of historic events, historic trails, sacred sites, or rural historic landscapes.	Avoidance and protection of those elements of the landscape that are essential to the historic setting of the property. If the setting cannot be avoided, the essential character of the setting may be documented, and the setting restored after completion of construction Aspects of the location, appearance, or operation of the undertaking may be modified to minimize intrusion on the historic setting. This might include stipulations on the height, color, emissions, or operational noise levels of facilities. Landscaping elements such as berms or screening by vegetation may be used to minimize intrusion on the historic setting.
Unintentional disturbance, looting, or vandalism.	All property types.	Control of access to the property by fencing, barriers, or monitoring. Restriction of activities near sensitive areas. If the property has been affected, an approved plan for damage assessment, recordation, or data recovery may be implemented.

Table 4–61 Previously Surveyed Area and Average Density of Known Cultural Resource Sites per Square Mile by Sub-watershed

Sub-watershed	Total Square Miles	Square Miles Surveyed	Percentage Surveyed	Sites per Square Mile
Little Bighorn River	77.5	0.6	0.7	13.3
Upper Tongue River	1,156.1	33.7	2.9	13.3
Middle Fork Powder River	725.7	23.8	3.3	[illegible]2.2
North Fork Powder River	32.3	0.4	1.3	15
Upper Powder River	2,505.5	229.4	9.2	5.0
South Fork Powder River	178.7	5.3	3.0	7.4
Salt Creek	238.1	11.3	4.7	7.9
Crazy Woman Creek	856.7	7.9	0.9	21.3
Clear Creek	855.4	6.7	0.8	45.2
Middle Powder River	350.4	31.9	9.1	5.2
Little Powder River	1,352.3	158.6	11.7	4.6
Little Missouri River	60.2	2.7	4.5	10.7
Antelope Creek	1,031.7	206.4	20.0	4.7
Dry Fork Cheyenne River	483.3	64.0	13.2	8.9
Upper Cheyenne River	323.1	131.2	40.6	5.2
Lightning Creek	481.8	62.2	12.9	4.5
Upper Belle Fourche River	1,320.1	245.3	18.6	4.3
Middle North Platte River	332.2	41.0	12.4	7.7
Total	12,361.1	1,262.4		
Average			10.2	6.1

It is assumed that the areas that have been inventoried for cultural resources in each sub-watershed are representative of the range of settings. It is further assumed that cultural resource sites are randomly distributed across the landscape. Given the total number of previously recorded sites per square mile for each watershed, the number of sites expected in the remaining unsurveyed areas is estimated. Table 4–61 shows the estimate of square miles of total disturbance as a result of the Proposed Action and each alternative and the number of cultural resource sites that may be affected by the proposed disturbance in each sub-watershed for the four alternatives.

Alternative 1

Alternative 1 is the Proposed Action. The total square miles of potential impact is 302.5. Assuming that site density is uniform throughout each sub-watershed, the number of sites per square mile from Table 4–62 is used as a multiplier to estimate the number of sites in the area of potential effect given the square miles of new disturbance. The number of cultural resource sites identified will be greater because an area larger than the proposed surface disturbance is surveyed. The potential number of sites affected by watershed varies from a high of 1,087 to a low of zero where there is no proposed development. All areas of ground disturbance associated with federal actions will be surveyed for cultural resources during the APD process. Until those surveys are completed, only rough estimates can be made of the actual number of eligible cultural resource sites that would be affected by the proposed oil and gas development and the nature of the effects.

Alternative 2

Alternative 2 differs from the Proposed Action in the methods of boosting compression and the strategies for produced water management. Although the number of proposed new wells to be developed in Alternative 2 is the same as the Proposed Action, the area of potential disturbance presented for Alternative 2 in Table 4–62 is different than is presented for the Proposed Action. Alternative 2 also includes two methods for handling produced water (2A and 2B), which differ slightly in the area that would be disturbed.

Table 4–62 Estimated Square Miles of Total CBM Surface Disturbance and Potentially Affected Cultural Resource Sites by Sub-watershed and Alternative

	Alternative 1		Alternative 2A		Alternative 2B		Alternative 3	
Sub-watershed	Square miles	Sites	Square Miles	Sites	Square Miles	Sites	Square miles	Sites
Little Bighorn River	0	0	0	0	0	0	0	0
Upper Tongue River	17.6	236	18.9	253	17.6	236	14.5	194
Middle Fork Powder River	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0
Upper Powder River	109.7	549	128.9	645	123.1	616	30.8	154
South Fork Powder River	0	0	0	0	0	0	0	0
Salt Creek	1.8	14	1.9	15	1.9	15	0.5	4
Crazy Woman Creek	22.6	479	26.4	565	25.0	535	7.9	169
Clear Creek	27.3	1,234	29.5	1,333	27.7	1,252	18.3	827
Middle Powder River	6.3	32	7.1	37	6.7	35	1.5	8
Little Powder River	24.0	110	25.7	118	24.6	113	12.4	57
Little Missouri River	0	0	0	0	0	0	0	0
Antelope Creek	70.4	401	70.9	404	70.6	402	25.9	148
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0
Upper Cheyenne River	5.2	27	5.4	28	5.2	27	2.4	12
Lightning Creek	0	0	0	0	0	0	0	0
Upper Belle Fourche River	48.0	206	48.0	206	47.4	204	28.5	123
Middle North Platte River	0	0	0	0	0	0	0	0
Total	332.9	3,288	362.7	3,604	349.8	3,435	142.7	1,696

The total square miles of potential impact for Alternative 2A is 316.5. The number of sites per square mile from Table 4-66 is used as a multiplier to estimate the number of sites in the area of potential effect given the square miles of new disturbance. This number is the estimated resources potentially affected. A larger number will be identified by surveys. The number of sites potentially affected by watershed varies from a high of 1,150 to a low of zero where there is no proposed development. Alternative 2B would result in less total surface disturbance

(311.3 square miles) and slightly fewer cultural resource sites potentially affected. All areas of ground disturbance associated with federal actions would be surveyed for cultural resources during the APD process. Until those surveys are completed, only rough estimates can be made of the actual number of eligible cultural resource sites that would be affected by the proposed oil and gas development.

Alternative 3

This alternative would result in no new federal wells. There would still be effects from development, drilling, and operations on private or state land. Some of the roads and water handling facilities would be located on federal lands. Federal agencies would allow these effects. Consequently, a small amount of federal land would be affected by private development in Alternative 3. The total square miles of potential effect for Alternative 3 is 104.7. The number of sites per square mile from Table 4–61 is used as a multiplier to estimate the number of sites in the area of potential effect given the square miles of new disturbance. The potential number of sites affected by watershed varies from a high of 568 to a low of zero where there is no proposed development. All areas of ground disturbance associated with federal actions will be surveyed for cultural resources during the APD process. Until those surveys are completed, only rough estimates can be made of the actual number of eligible cultural resource sites that would be affected by the proposed oil and gas development.

The discussions of each alternative address the total number of cultural resource sites that may be directly affected by the extent of proposed surface disturbance for each alternative. All of the federal undertakings would be subject to Section 106 review under the implementing regulations of the NHPA. From 39 to 43 percent of the proposed development in Alternatives 1, 2A, and 2B would be non-federal actions that are not subject to Section 106 review, and only a small proportion of the access roads and water handling facilities in Alternative 3 would be on federal surface and subject to Section 106 review. Based on the proportion of known sites that are considered historic properties, only about 15 percent of the cultural resource sites that may be affected would be historic properties.

Based on the estimated number of cultural resources potentially affected by Alternative 3 and the estimate that about 15 percent of recorded sites are typically evaluated as eligible, 178 historic properties would be within the potential area of direct surface disturbance of Alternative 3 and the non-federal portions of the other alternatives. These resources would not be protected by the Section 106 process. The approximate numbers of historic properties that are likely to be taken into consideration in the Section 106 process for potential direct effects are 257 for Alternative 1, 283 for Alternative 2A, and 271 for Alternative 2B. Current data are inadequate to estimate how many historic properties may require consideration for indirect effects. Indirect effects are most likely to be an issue for sites, districts, or landscapes that are eligible for their association with events, patterns of events or historic persons. The information in the Wyoming Cultural Records Office database is site-specific and cannot provide information on potential indirect effects to cultural districts or landscapes. Cultural landscapes and sites that are eligible as the locations of events important in history may be susceptible to indirect auditory and visual effects from varying distances. These effects cannot be derived from the database or basic documentation, but must be identified in the field.

Although some historic properties would require additional investigations after initial survey and documentation to complete evaluation or to confirm their boundaries, it would be feasible to avoid and protect the majority of the historic properties, possibly 95 percent or more. If it is assumed that the distribution of historic properties across the landscape is uniform, it can be estimated that the number of historic properties that cannot be avoided by the direct effects of federal actions and would require mitigation measures such as stabilization, rehabilitation, detailed recordation, or data recovery would be approximately 13 to 14 (for example, Alternative 1: 257 historic properties times 5 percent equals 13). In fact, site distributions are not uniform, and each historic property must be considered individually. Over time, as the opportunities for well locations are used, the prospects to avoid effects to historic properties would diminish, and the potential for inadvertent indirect effects would increase.

Based on the currently known site densities and the assumptions above, the cumulative effects of the proposed developments would be that 178 historic properties may be directly affected by state and private actions, and that the Section 106 process for federal actions would avoid or minimize effects to 257 to 283 historic properties. Minimizing effects may include mitigation measures at 13 to 14 historic properties. In addition, oil and gas development would improve access areas where historic properties are located, increase traffic and activities near many sites, and increase the potential for inadvertent effects from unrelated actions.

Management Options

Because of the requirements for compliance with federal regulations including, but not limited to Section 106 of the National Historic Preservation Act, NEPA, and the Archeological Resources Protection Act, all areas on federal lands or that involve federal minerals proposed for disturbance will be inventoried for cultural resources. Equivalent regulatory mandates are not in place for private or State of Wyoming lands. However, if a project involves a federal permit or authorization, federal historic preservation requirements would apply.

It is evident that all of the alternatives have the potential to affect historic properties. As development progresses the opportunities for avoiding direct or indirect effects to historic properties will diminish. As more wells are developed it would become increasingly difficult to avoid visual and auditory impacts to cultural landscapes. Because of long-term planning and management considerations, cultural resource inventories should target entire PODs rather than piecemeal actions.

The following types of management situations may be encountered:

1. The resource is not a historic property, and no further work is required. The majority of cultural resources are not historic properties;

2. **The historic property is within an area of proposed disturbance, but the proposed action can be altered within areas of existing inventory to avoid direct adverse effects and protect the property from indirect adverse effects;**
3. **The historic property is within an area of proposed disturbance but the proposed action can be altered, relocated, or constrained within areas of existing inventory so that only non-contributing portions of the historic property are affected and contributing portions can be protected from adverse impact;**
4. **The historic property is not immediately within the area of proposed impact, but its location and setting are intrinsic to its eligibility, and the proposed action can be altered, relocated, or constrained in such a way that its intrusion on the viewshed and adverse effect contributing to aspects of the setting can be minimized;**
5. **The historic property is within an area of proposed impact but is a small property eligible under Criteria c or d and the property itself, its significant attributes, or its important data are not intrinsically tied to their location or setting and can be moved, collected, documented, or studied at minimal cost;**
6. **The historic property and feasible design of the proposed action are such that avoidance and protection of the property is not a viable alternative. In such a case, the cultural resource professional would propose a prudent and feasible recordation or data recovery plan to submit to BLM for review; or**
7. **The historic property was not identified or predicted by the cultural resource inventory and was encountered during development or operation of the facilities.**

Monitoring would assess the effectiveness of management strategies in achieving management objectives. If management activities are not achieving these objectives, the strategies would be modified to improve their effectiveness.

Land Use and Transportation

Land Use

This section discusses the potential effects to land ownership, land uses, and land management plans in the Project Area.

Land Status/Ownership

Surface or mineral ownership would not be expected to change by implementation of any of the alternatives. No direct or indirect effects to existing surface land ownership or mineral ownership would occur under implementation of any of the alternatives.

Surface use and rights-of-way approvals would be obtained from federal, state, and local agencies. Access easements would be negotiated with landowners or secured through the permitting processes of the federal, state, or local jurisdictional agencies. For Alternative 1 and Alternative 2, most of the proposed wells and ancillary facilities would be located on lands where the federal government

BEST COPY AVAILABLE

owns the CBM mineral estate. However, not all of the surface may be federally owned.

Land Use

This section discusses the short-term and long-term direct and indirect effects to existing land uses that are anticipated to occur from implementation of the project.

Direct and Indirect Effects

Rangeland is the primary land use that would be affected by any of the alternatives for both public and private lands in the Project Area. Direct effects to land uses result from removal or loss of existing land uses caused by direct disturbances for the project-related facilities or activities, and occur at the same time and place as the project-related action. Direct effects to land uses would occur from construction of the proposed facilities for any of the alternatives. The acres of disturbance for each of the alternatives are estimated based on the proposed number and tentative locations of wells and other project facilities. Facility-specific disturbances were estimated using data collected from existing oil and gas development in the Project Area.

Indirect effects to land uses are reasonable foreseeable results of project-related activities that occur later or are removed in distance from the project-related action. Indirect effects may occur to land uses on properties adjacent to the project-related facilities for any the alternatives. For example, project-related vehicles and equipment may generate air emissions, fugitive dust, noise, and increased risk of traffic accidents and visual and aesthetic effects may result from project-related facilities and activities. Land disturbances also increase the potential for the introduction and spread of noxious weeds.

Alternative 1

Effects to land uses are addressed for the two primary phases of the Proposed Action: drilling and construction of facilities (short-term disturbances), and production and maintenance (long-term disturbances) After decommissioning, reclamation, and final closure of project-related facilities, the pre-existing land uses would be re-established.

The land use disturbances associated with the Proposed Action include two primary components. The first is the CBM wells and ancillary facilities. The second component is the non-CBM wells and ancillary facilities. Under the Proposed Action, wells and ancillary facilities would be installed and operated within 10 of the 18 sub-watersheds that make up the Project Area. Most of the new wells (64 percent) and facilities would be constructed in two sub-watersheds: the Upper Powder River and Upper Belle Fourche River sub-watersheds. Other sub-watersheds that would contain relatively high numbers of wells and facilities include Clear Creek, Crazy Woman Creek, Antelope Creek, Little Powder River, and Upper Tongue River.

For the CBM wells, implementation of this alternative would cause short-term disturbance of as many as 193,589 acres. The short-term disturbance associated with Alternative 1 would involve about 3 percent of the almost 8 million-acre Project Area. Under the Proposed Action, surface disturbances and effects to existing land uses would occur during drilling and construction of the proposed facilities, including well pads, CMFs, roads, pipelines, power lines, compressor stations, and water-handling facilities. Most of the short-term disturbance would be associated with construction of the pipelines, roads, and water-handling facilities. Compressor stations would account for a small portion of the overall disturbance.

After the proposed facilities have been installed, much of the disturbed land would be reclaimed, revegetated, and returned to pre-existing land uses. After pipelines have been reclaimed and well pads and compressor stations reclaimed in part, long-term disturbance associated with the new CBM wells would encompass about 85,884 acres. The acreage for long-term disturbance is a 45 percent reduction from the short-term disturbance. The roads and water handling facilities would represent most of the long-term disturbance.

A large portion of the disturbances associated with the Proposed Action involve the large water-handling facilities that would be constructed to contain the produced water over the life of the project. Approximately 27,009 acres of total surface area would be disturbed both short-term and long-term for the water handling facilities for the Proposed Action. Most of this disturbance would occur within the Upper Powder River and Upper Belle Fourche River sub-watersheds.

In addition to the disturbances associated with the CBM wells, about 3,200 non-CBM wells would also be completed over a 10-year period as part of the Proposed Action. Of these wells, 3,000 would be drilled within the Buffalo Field Office Area and 200 wells would be located within the Casper Field Office Area. Short-term disturbance associated with construction of non-CBM wells and associated facilities would affect 8,800 acres of the Project Area. Most of this disturbance would occur in three watersheds: Little Powder River, Upper Belle Fourche River, and Upper Powder River. After the non-CBM wells are operational and partial reclamation has occurred, the long-term disturbance would be reduced to 85 percent of the original disturbance, or 7,520 acres.

Rangeland is the predominant land use that would be displaced by project-related facilities for both the short-term and long-term cumulative proposed disturbance, as shown on Table 4–63 and Table 4–64. The cumulative total disturbance shown on Table 4–63 does not include that acreage that would be disturbed by the CMFs or water handling facilities because the locations proposed for these facilities are not yet defined. As shown in Table 2–41, 80 percent of the CBM well pads would be located on private land. Almost 90 percent of the land disturbed would be rangeland. Two percent of the total rangeland in the Project Area would be affected under implementation of Alternative 1.

Direct effects to existing land uses would result from clearing of or damage to vegetation and disturbance of soils for construction and installation of the proposed facilities. Implementation of the Proposed Action could have both positive and negative direct and indirect effects on the amount of grazing capacity and AUMs for the rangeland in the Project Area. Potential direct impacts to rangeland would include loss of vegetation or forage for livestock grazing that would

BLANK PAGE

Table 4–63 Projected CBM Disturbances of Alternatives 1, 2A, and 2B to Land Uses by Type of Land Use and Sub-watershed

Alternatives 1, 2A, 2B
Proposed Disturbance by Sub-watershed (Acres)

	Agriculture		Barren		Forested		Mixed Rangeland		Wetlands		Urban		Water		Coal Mines		Total	
Sub-watershed	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Little Bighorn River	3	2	0	0	0	0	11	9	0	0	0	0	0	0	0	0	14	12
Upper Tongue River	665	262	0	0	329	121	6,459	2,324	0	0	3	2	0	0	0	0	7,455	2,708
Middle Fork Powder	3	2	0	0	19	16	44	38	0	0	0	0	0	0	0	0	66	56
North Fork Powder	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	3	2
Upper Powder	1,520	549	3	1	1,367	496	52,950	19,256	0	0	93	34	4	1	0	0	55,938	20,338
South Fork Powder	0	0	0	0	3	2	6	5	0	0	0	0	0	0	0	0	8	7
Salt Creek	0	0	0	0	6	5	1,164	432	0	0	0	0	0	0	0	0	1,169	437
Crazy Woman Creek	9	3	0	0	8	4	11,145	3,914	157	49	60	21	0	0	0	0	11,379	3,991
Clear Creek	967	330	4	1	194	63	10,503	3,744	0	0	12	4	144	51	0	0	11,825	4,195
Middle Powder River	81	44	0	0	284	134	2,859	1,162	0	0	0	0	0	0	0	0	3,224	1,340
Little Powder River	1,719	705	0	0	552	454	14,180	6,756	0	0	104	36	31	14	6	5	16,591	7,970
Little Missouri	14	12	0	0	3	2	242	207	0	0	0	0	0	0	0	0	259	221
Antelope Creek	7,411	2,616	26	9	8	7	31,128	11,074	0	0	0	0	0	0	3	2	38,576	13,709
Dry Fork Cheyenne	14	12	0	0	3	2	118	101	0	0	0	0	0	0	0	0	135	115
Upper Cheyenne	504	181	10	5	3	2	2,629	1,031	27	11	3	2	7	2	6	5	3,188	1,239
Lightning Creek	19	16	0	0	0	0	116	99	0	0	0	0	0	0	0	0	135	115
Upper Belle Fourche	3,481	1,342	199	70	115	94	20,418	7,885	11	5	164	73	0	0	25	21	24,414	9,492
Middle North Platte Casper	3	2	3	2	0	0	99	85	0	0	0	0	0	0	0	0	105	89
Total	16,413	6,079	245	89	2,893	1,405	154,072	58,123	194	65	439	173	186	69	39	33	174,481	66,036

Table 4–64 Projected CBM Disturbances of Alternatives 1, 2A, and 2B to Land Uses by Type of Land Use and Surface Owner

	Alternatives 1, 2A, 2B Proposed Disturbance by Surface Owner (Acres)											
	BLM											
Sub-watershed	BFO		CFO		Forest Service		State		Private		Total	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Agriculture	7	3	0	0	1,658	592	507	184	14,240	5,301	16,413	6,079
Barren	0	0	0	0	0	0	113	40	132	49	245	89
Forested	453	222	6	5	39	33	186	101	2,211	1,044	2,893	1,405
Mixed Rangeland	18,216	6,772	30	26	5,243	2,169	10,201	3,838	120,381	45,319	154,072	58,123
Wetlands	0	0	0	0	3	1	3	2	188	62	194	65
Urban	27	9	0	0	0	0	15	7	398	158	439	173
Water	0	0	0	0	0	0	26	9	160	60	186	69
Coal Mine	0	0	0	0	0	0	0	0	39	33	39	33
Total	18,702	7,006	36	31	6,943	2,795	11,050	4,180	137,749	52,025	174,481	66,036

BLANK PAGE

result from the land disturbances associated with construction, and an increased potential to introduce and spread noxious weeds.

Under the Proposed Action, potential indirect impacts to rangeland and other land uses could result from surface disturbances that introduce nonnative, non-palatable plant species for cattle or other livestock. The BLM does not allow non-native species in reclamation mixes on federal lands. However, the BLM does not dictate the plant species that are required by private landowners. The land management practices and strategies to prevent and control the spread of noxious weeds are discussed under Mitigation.

Land disturbances would result in a reduction in the grazing capacity and the loss of 2 percent of the rangeland and associated AUMs in the Project Area. However, the number of AUMs could increase in areas where produced water from CBM development is used to improve rangelands by irrigation. CBM produced water could be applied through land application, irrigation, discharge, or storage in upland areas. Construction of stock ponds and irrigation systems could allow increased forage and grazing. The increased availability for stock watering could, however, increase the potential for overgrazing. Potential effects could include an increase in the number of AUMs, overgrazing, and introduction of noxious weeds. These effects would vary based on the quality of the produced water and site-specific conditions such as soil type and existing rangeland vegetation.

The potential impacts to land use associated with the Proposed Action include the cumulative threshold effects of SAR and salinity that would result from the application of water produced by CBM development to crops and rangeland, such as irrigation or land application. The land application of produced water in upland areas has the potential to have both positive and negative effects on land uses. The effects of irrigation or submersion on crops and rangeland vegetation would vary based on the quality of the produced water to be used for irrigation and other site-specific conditions, such as soil clay mineralogy and chemistry, individual plant tolerances to SAR and salinity, and water management practices. The productivity and yield of crops or rangeland grazing capacity may be reduced by the use of irrigation water with high SAR and salinity values. SAR values of 13 or more may cause practically irreversible changes to soil structure that may impact crops or rangeland vegetation (Seelig 2000; U.S. Salinity Laboratory Staff 1954). As indicated in Section 4, Surface Water, the predicted average SAR values for undiluted produced waters range from 6.4 in the Upper Cheyenne River sub-watershed to 38.7 for the Upper Tongue River sub-watershed. The predicted salinity values for irrigation water (ECw) for the undiluted produced water in the sub-watersheds of the Project Area range from 0.6 to 2.4 mmhos/cm. For potential yields of 100 percent, typical relative tolerances for field crops to salinity in irrigation water (EC) generally range from 0.7 to 5.3 mmhos/cm (EPA 2002b).

Discharges of produced waters and their use for irrigation would be in accordance with the guidance and requirements of the State of Wyoming. The specific locations for the wells and water handling facilities are not yet defined; therefore, site-specific impacts to crops and rangeland plants are not quantifiable at this time. Site-specific assessments of these impacts are required as part of the APD approval process. Implementation of the MMRP provided in Appendix D would minimize the potential effects to land use associated with SAR, salinity, and standing water (such as during flood irrigation).

The predicted average SAR values for the produced water in each sub-watershed, and the suitability of the produced water for irrigation are analyzed in Surface Water. Possible guidelines for establishing SAR and salinity limits for irrigation water are provided in Soils. Potential impacts to vegetation from each alternative are analyzed in Vegetation.

Indirect adverse effects may occur to the land uses on properties adjacent to the project-related facilities from implementation of the Proposed Action through generation of air emissions, fugitive dust, and noise, visual and aesthetic effects of the project-related facilities and activities, increased traffic levels from project-related vehicles, and increased opportunities for public access as a result of the development of new and upgraded access roads for the life of the project.

An analysis of the potential impacts associated with air emissions, fugitive dust, and noise is provided in Air Quality and Climate and Noise. Visual effects are analyzed in Visual Resources.

The anticipated impacts to the recreational land uses and visual resource areas, such as WSAs and other SMAs on BLM lands, are analyzed in Recreational Resources, and Visual Resources. No surface occupancy (NSO) for mineral development has been stipulated for the Fortification Creek WSA and most of the other SMAs. No direct land use impacts would occur in the Fortification Creek WSA, Cantonment Reno, or Weston Hills Recreation Areas because no project-related facilities are proposed in these areas. Indirect effects to these areas may include some visible project facilities, noise, and increased access and human activity associated with CBM development. There would be no effects to recreational uses within the other SMAs in the Project Area because they are located 10 miles or more outside of the coal boundaries in the Middle Fork Watershed.

Alternatives 2A and 2B

With the exception of the overall methods for handling the disposal of produced water, the land use effects associated with implementation of Alternatives 2A and 2B are similar to those for the Proposed Action.

For both Alternative 2A and 2B, the number and distribution of CBM and non-CBM wells are the same as evaluated for Alternative 1. Short-term disturbances for non-CBM wells would be 8,800 acres, and long-term disturbances would be 7,520 acres.

For Alternative 2A, short-term disturbance from CBM development would be 202,843 acres of total surface area. Long-term disturbance associated with Alternative 2A would be 95,138 acres. Much of this long-term disturbance would be associated with 36,263 acres of surface area that would be disturbed for the water handling facilities to contain the produced water from the proposed CBM wells.

For Alternative 2B, short-term disturbance from CBM development would be 199,233 acres of total surface area. Long-term disturbance would be

BEST COPY AVAILABLE

91,528 acres, of which 32,653 acres would be associated with the water handling facilities.

For both Alternative 2A and Alternative 2B, rangeland is the predominant existing land use that would be displaced by the project-related facilities for both the short-term and long-term effects. The potential disturbance from non-CBM wells and indirect impacts to land uses would be about the same as were described for Alternative 1.

Alternative 3

There would be no new federal wells under this alternative. However, development of non-federal CBM wells would continue to occur on non-federal lands within the Project Area. The agencies assumed development of private and state minerals would occur along the same overall schedule as for Alternative 1. The Companies would drill approximately 15,504 new CBM wells between 2002 and 2011. These wells would be in addition to the 12,024 CBM wells already permitted or drilled on federal, state, and private lands within the Project Area. A total of 27,528 CBM wells would be developed by 2011 under this alternative. An additional 1,302 non-CBM wells would be installed under Alternative 3.

As described under Alternative 1 and Alternatives 2A and 2B, some of the new CBM wells would be drilled from the same well pads; therefore, the number of pads constructed would be less than the number of wells drilled.

Because fewer new wells would be drilled and fewer pads, roads, and pipelines would be constructed under Alternative 3, the number of facilities constructed would be smaller than under the Proposed Action. The overall short-term and long-term disturbances associated with this alternative would be less than that which would occur with implementation of Alternative 1 or Alternatives 2A or 2B. Rangeland is the predominant land use that would be displaced by project-related facilities for both the short-term and long-term cumulative disturbance proposed (for both CBM and non-CBM wells), as shown in Table 4–65 and Table 4–66.

Short-term direct adverse effects to land uses would result from clearing or damage to vegetation and disturbance of soils for drilling and construction of facilities. For Alternative 3, short-term direct effects associated with the CBM wells would displace approximately 79,052 acres from the existing land uses, primarily rangeland. In addition, 3,581 surface acres would be disturbed by construction of non-CBM wells. Most of this disturbance would occur in three sub-watersheds. They are the Little Powder River, Upper Belle Fourche River, and Upper Powder River.

Long-term direct effects to land uses would result from production and maintenance for the life of the project. Once the CBM wells are operational and partial reclamation has occurred, long-term direct effects associated with the CBM wells would displace 35,458 acres from the existing land uses, primarily rangeland. Approximately 11,683 acres of the total long-term disturbance would be displaced for the water handling facilities to contain the produced water from the

Table 4–65 Projected CBM Disturbances of Alternative 3 to Land Uses by Type of Land Use and Sub-watershed

Alternative 3
Proposed Disturbance by Land Use Type(Acres)

	Agriculture		Barren		Forested		Mixed Rangeland		Wetlands		Urban		Water		Coal Mine		Total	
Sub-watershed	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Little Bighorn River	3	2	0	0	0	0	11	9	0	0	0	0	0	0	0	0	14	12
Upper Tongue River	659	260	0	0	218	81	5,720	2,045	0	0	3	2	0	0	0	0	6,600	2,388
Middle Fork Powder	3	2	0	0	0	0	19	16	0	0	0	0	0	0	0	0	22	19
North Fork Powder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder	1,140	411	0	0	472	171	11,544	4,234	0	0	48	18	0	0	0	0	13,204	4,834
South Fork Powder	0	0	0	0	3	2	6	5	0	0	0	0	0	0	0	0	8	7
Salt Creek	0	0	0	0	0	0	565	205	0	0	0	0	0	0	0	0	565	205
Crazy Woman Creek	9	3	0	0	8	4	3,680	1,287	5	2	28	10	0	0	0	0	3,729	1,306
Clear Creek	967	330	0	0	184	58	6,782	2,418	0	0	12	4	144	51	0	0	8,088	2,861
Middle Powder River	33	21	0	0	54	23	463	205	0	0	0	0	0	0	0	0	550	249
Little Powder River	1,372	560	0	0	122	99	6,055	2,752	0	0	78	27	29	11	6	5	7,661	3,454
Little Missouri	8	7	0	0	0	0	83	71	0	0	0	0	0	0	0	0	91	78
Antelope Creek	3,586	1,262	0	0	0	0	10,237	3,633	0	0	0	0	0	0	0	0	13,823	4,895
Dry Fork Cheyenne	8	7	0	0	0	0	36	31	0	0	0	0	0	0	0	0	44	38
Upper Cheyenne	210	76	10	5	0	0	1,196	469	13	6	0	0	0	0	6	5	1,434	560
Lightning Creek	14	12	0	0	0	0	55	47	0	0	0	0	0	0	0	0	69	59
Upper Belle Fourche	2,664	1,040	191	67	11	9	11,591	4,482	7	4	164	73	0	0	17	14	14,645	5,689
Middle North Platte Casper	0	0	3	2	0	0	44	38	0	0	0	0	0	0	0	0	47	40
Total	10,676	3,993	203	74	1,070	448	58,086	21,944	25	11	333	135	173	63	28	24	70,594	26,693

BEST COPY AVAILABLE

Table 4–66 Projected CBM Disturbances of Alternatives 3 to Land Uses by Type of Land Use and Surface Owner

	Alternative 3 Cumulative Disturbance by Surface Owner (Acres)											
	BLM											
	BFO		CFO		Forest Service		State		Private		Total	
Land Use Type	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Agriculture	0	0	0	0	508	179	481	175	9,687	3,640	10,676	3,993
Barren	0	0	0	0	0	0	113	40	91	35	203	74
Forested	0	0	0	0	3	2	175	91	893	355	1,070	448
Mixed Rangeland	0	0	0	0	664	270	9,516	3,581	47,906	18,093	58,086	21,944
Wetlands	0	0	0	0	0	0	3	2	22	9	25	11
Urban	0	0	0	0	0	0	15	7	318	128	333	135
Water	0	0	0	0	0	0	26	9	147	54	173	63
Coal Mine	0	0	0	0	0	0	0	0	28	24	28	24
Total	0	0	0	0	1,174	452	10,328	3,905	59,064	22,313	70,594	26,693

proposed CBM wells. The long-term disturbance from the non-CBM wells is estimated to be an additional 3,060 acres.

Under Alternative 3, the existing land uses in the Project Area would continue to experience long-term indirect effects from air emissions, fugitive dust and noise, visual and aesthetic effects of the project-related facilities and activities, increased traffic levels from project-related vehicles, and increased public access opportunities as a result of the development of new and upgraded access roads for the life of the project. Short-term indirect adverse effects to the land uses on properties adjacent to the project-related facilities would also occur through physical intrusion of the construction crew and equipment and the temporary obstruction or delay of traffic at road crossings during the construction and installation phase.

Consistency with Land Use Plans

Implementation of Alternative 1 or Alternatives 2A and 2B would be consistent with land use plans of the State of Wyoming, the planning goals of the four counties, and planning goals of numerous incorporated areas within the Project Area. The results of the analysis of federal land use plans are presented in Chapter 5.

Although some of the proposed wells are within or near incorporated areas, primarily near the City of Gillette, zoning regulations allow oil and gas development within designated zoning districts.

Cumulative Land Use Effects

Under Alternative 1 or Alternatives 2A and 2B, the Companies would drill, complete, and operate an additional 39,367 new CBM wells within the Project Area by the end of 2011. Including the 12,024 CBM wells already permitted in the Project Area, Alternative 1 or Alternatives 2A or 2B would have a cumulative total of 51,391 new CBM wells and 3,200 non-CBM wells within the Project Area by the end of 2011. The life of the project for these alternatives would be 20 years and project-related activities would be completed around 2021.

Under Alternative 3, the Companies would drill approximately 15,504 new non-federal CBM wells between 2002 and 2011. These wells would be in addition to the 12,024 CBM wells already permitted or drilled on federal, state, and private lands within the Project Area. A cumulative total of 27,528 CBM wells would be developed by 2011 for this alternative. An additional 1,302 non-CBM wells would be installed under Alternative 3.

A comparison of acres of the total surface area disturbed for the project facilities associated with each alternative is shown on Table 2–41. Both short-term and long-term disturbances would be substantially less for Alternative 3 than for Alternative 1 or Alternative 2.

Transportation

This section analyzes the potential effects of construction and operation of the proposed facilities on the transportation resources within the Project Area.

268

BEST COPY AVAILABLE

For any of the alternatives, the potential direct effects to transportation resources would include a significant amount of increased vehicular traffic and risk of traffic accidents on existing roadways in the Project Area from daily travel of project-related employees. Indirect effects would include minor traffic delays from short-term closures at some road crossings, increased wear and tear on existing roads, additional air emissions, fugitive dust from roads, noise, increased potential access to remote areas, an increased risk of vehicle collisions with livestock and wildlife, and visual intrusion of project-related vehicles and activities.

For any of the alternatives, the proposed new roads to access well pads (resource roads) would be developed in accordance with accepted current transportation practices of the oil and gas industry. New resource roads on BLM or FS lands would meet the minimum BLM requirements for road design and maintenance, as defined in the APD and ROW applications.

The specific locations for the wells, new resource roads, and other project-related facilities are not yet defined; therefore, site-specific impacts to traffic and roads are not quantifiable at this time. Site-specific assessments of these impacts are required as part of the APD approval process.

Rail service and airports within the Project Areas would not be affected by any of the alternatives. Drilling operations for any of the alternatives would comply with the requirements of the Federal Airport Regulation Sub-Part 77 (FAR Part 77). Obstructions to air navigation are defined as any structure that is 200 feet above ground level or above the established airport elevation, whichever is higher, and within 3 miles of the established airport reference point. The FAA Form 7460–1, "Notice of Proposed Construction of Proposed Construction or Alternation," is required to be submitted to FAA at least 30 days before construction begins near an airport.

The transportation-related impact analysis assumed that:

- The construction and installation phase for any of the alternatives would occur within the entire Project Area over a 10-year period. Short-term and long-term increases in daily traffic would result from the proposed activities for any of the alternatives.
- Equipment needed for construction and installation of the proposed facilities for any of the alternatives would include heavy equipment (mobile drilling rig, bulldozers, graders, track hoes, trenchers, and front-end loaders), and heavy- and light-duty trucks.
- Short-term increases in daily traffic were assessed for all the alternatives based on the daily travel of the average number of estimated workers for the peak activity year for all project-related activities.
- Increases in average daily traffic counts would occur on the primary access roads into the Project Area, predominantly Interstate 25, Interstate 90, U.S. Highways 14 and 16, State Highways 59 and 387, and the county roads.
- An average of 1.5 workers per vehicle was assumed to compute the increases to average daily traffic count for the roads in the Project Area attributable to project-related vehicle trips for all of the alternatives. Each worker was assumed to make one round trip per day.

- No new public roadways or new intersections would be built under any of the alternatives.
- A significant traffic volume impact would occur if the project-related vehicle trips generate a 25 percent or more increase in the average daily traffic count compared with the existing (background) average daily traffic counts for the major access roads in the Project Area.
- An increase in the accident rate is likely at intersections, or locations such as where a lane merges, if the increase in number of vehicles that enter existing intersections is significantly higher (10 percent of more) than background conditions.

Alternative 1

For the Proposed Action, the direct effects to transportation resources would include a significant increase in vehicular traffic (more than 25 percent increase compared with existing traffic counts) on existing roadways in the Project Area from daily travel of project-related employees. The risk of traffic accidents would increase on roads used to access the Project Area in proportion to the additional traffic.

Under the Proposed Action, approximately 7,135 miles of new improved and 10,619 miles of two-track roads would be developed with the new CBM facilities. The Companies would pay the costs associated with construction, maintenance, and reclamation of proposed new resource roads. The counties and Companies would be responsible for maintaining the project's improved roads in the Project Area. The counties would continue to maintain the existing county roads and any roads covered by maintenance agreements with BLM. The Companies would maintain all other project roads. The Companies would not routinely employ dust abatement procedures on the roads in the Project Area during production and maintenance.

For the Proposed Action, the estimated CBM and non-CBM employment for each year of the project for all project-related activities is provided in Tables 2–16 and 2–20. Under implementation of Alternative 1, the estimated number of cumulative employees for the peak activity year 2007 was used to calculate the maximum number of additional project-related vehicle trips for short-term effects.

Transportation-related effects from implementation of the Proposed Action are summarized as follows:

- In the short term, the average daily traffic would increase by approximately 7,627 additional vehicle trips (based on an estimated 5,620 workers per day) during the peak activity year (2007), distributed over the various roads within the entire Project Area.
- Long-term increases in traffic would vary proportionately with the number of employees and activities required for each year of the project.
- Based on the proposed well locations, 63 percent of the additional daily traffic caused by project-related vehicles would occur within the Upper Powder River and Upper Belle Fourche River sub-watersheds. Project-related traffic

BEST COPY AVAILABLE

would be dispersed throughout these two sub-watersheds and would result in a relatively large increase in traffic on state and local roads during the life of the project. The increased volume primarily would affect State Highways 59 and 387.

- Most of the remainder of the additional daily traffic from project-related vehicles would occur in the Clear Creek, Crazy Woman Creek, Upper Tongue River, Antelope Creek, and Little Powder River sub-watersheds as a result of the relatively high numbers of proposed wells and facilities.
- The estimated increases to average daily traffic attributable to project-related vehicles is more than a 25 percent increase compared with the existing average daily traffic counts for some of the roads in Project Area.
- The estimated increase in risk of traffic accidents from additional project-related vehicles would be approximately the same percent increase as for the average daily traffic counts caused by project-related vehicles compared with the existing daily traffic counts for the roads in the Project Area.
- Indirect effects would include minor traffic delays from short-term closures at some road crossings, increased wear and tear on existing roads, additional air emissions, fugitive dust from roads, noise, increased potential access to remote areas, an increased risk of vehicle collisions with livestock and wildlife, and visual intrusion of project-related vehicles and activities.

Alternatives 2A and 2B

Under implementation of Alternatives 2A or 2B, the effects to transportation resources would be similar to those described for Alternative 1 and would include a significant amount of increased vehicular traffic and a proportionate risk of traffic accidents on existing roadways in the Project Area from daily travel of project-related employees.

Alternative 3

Because fewer new wells would be drilled and fewer pads, roads, and pipelines would be constructed under Alternative 3, the number of average workers per day would be less than that under the Proposed Action. The direct effects to transportation resources from Alternative 3 would include a significant amount of increased vehicular traffic (more than 25 percent), and a proportionate risk of traffic accidents on existing roadways in the Project Area from daily travel of project-related employees. For Alternative 3, the estimated CBM and non-CBM employment for each year of the project for all project-related activities is provided in Tables 2–36 and 2–40. The estimated number of employees for the peak activity year (2007) was used to calculate the maximum number of additional project-related vehicle trips for short-term effects. Based on a cumulative total of 1,237 workers for all activities, the average daily traffic would increase by 1,649 additional vehicle trips, distributed over the various roads within the Project Area for the peak activity year for Alternative 3. The long-term increases in traffic would vary proportionately with the number of employees and activities required for each year of the project.

Cumulative Transportation Effects

Direct effects to the primary access routes within the Project Area, including state, BLM, FS, and county roads, would occur as a result of project-related vehicular traffic associated with implementation of any of the alternatives. The additional traffic is expected to increase the rate of degradation of the existing public roadways in the Project Area, primarily in the Upper Powder River and Upper Belle Fourche River sub-watersheds.

Because the number of traffic accidents has increased on some county and state roads in areas of existing CBM development, an increased risk of traffic accidents is likely in proportion to the amount of increased daily traffic for any of the alternatives. The cumulative transportation effects associated with additional vehicle trips under implementation of Alternatives 1, 2A or 2B would be considerably greater compared with Alternative 3. Additional traffic, risks of accidents, and indirect effects would be proportionate to the number of employees and activities for each year of the project. Increased degradation of existing roadways may result from any of the alternatives. Based on the distribution of the tentative well locations for Alternatives 1, 2A, and 2B, wear and tear on roads would likely occur in all four counties, primarily in Johnson and Campbell Counties. Under implementation of Alternative 3, wear and tear on roads would likely occur primarily in Johnson, Sheridan, and Campbell Counties.

The cumulative impacts to transportation resources also include the potential for overlapping restrictions and federal stipulations to affect the ability of the operators to obtain access to leases on private or state lands. Access for entry to state or private lands that are surrounded by federal lands is not likely to be limited by federal mitigation requirements for CBM development in the Project Area.

Visual Resources

Development of coal bed methane in the Project Area would alter the physical setting and visual quality of the landscape and would affect the landscape as experienced from sensitive viewpoints, including travel routes and popular use areas. The proposed facilities would introduce new elements into the landscape and would alter the existing form, line, color, and texture, which characterize the existing landscape. The landscape provides a scenic setting for recreational and residential uses of the area.

Direct effects to visual resources occur as a result of the disturbance of the landscape by project activities and the addition to the landscape of proposed facilities, including the well pads, pumping units, compressors, and associated electric power lines, pipelines, and access roads. Direct effects can be short or long term.

Short-term effects result from temporary disturbances to visual resources, including construction and installation activities. Short-term effects to the visual character of the landscape can result from construction of small temporary pits on drill sites, well drilling, and construction of ancillary facilities, such as access roads, pipelines, power lines, CMFs, and compression stations.

Long-term effects result from the addition of permanent structures to the landscape and from operation of facilities. Long-term disturbance would result from the development of wells pads, CMFs, improved and two-track access roads, power lines, and compressor stations. Effects from long-term disturbance would occur over the expected 20-year life of the project. The largest effects would occur from the addition to the landscape of wells and the disturbances that result from the removal of vegetation on well pad areas and access roads. Each two-track well access road would connect with local roads that provide access into the Project Area. All gathering lines, water lines, high-pressure gas lines, and underground electrical cables would be located along road ROWs wherever feasible, and would likely result in visual effects that exceed the access roads alone.

Alternative 1

Construction Disturbance

Short-term effects during the 10-year construction period to the visual character of the landscape at each well pad would result from well pad construction, well drilling, and associated construction of ancillary facilities, such as access roads, power lines, pipelines, and compressor stations. Construction and installation of pipelines would immediately follow construction of access roads and well pads and would coincide with completion of well drilling. Each access road to a well pad would connect with local roads that provide access in the Project Area. All gathering lines, water lines, high-pressure gas lines and power lines would be located adjacent to road ROWs. A summary of estimated short-term disturbance from each type of facility within each sub-watershed is provided in Chapter 2.

The short-term disturbance associated with implementation of this alternative could disturb as many as 202,389 acres or 3 percent of the Project Area. Most of the disturbance would occur on federal, state, and private lands inventoried with VRM Class IV. Most of the disturbance would result from construction of pipelines and roads. Temporary disturbances would not conflict with VRM objectives because for each well pad and associated access road and power line, construction disturbances would occur over a period of less than 2 years, after which they would be reclaimed back to long-term disturbances associated with operations and maintenance. VRM objectives address modifications to the landscape from long-term facilities.

Drill site preparation, drilling, and well completion are generally short-term effects. Drilling would occur over a 10-year period throughout the Project Area. Drilling associated with individual wells would be short term, typically occurring 24 hours per day for a 1- to 3-day period for each well. Drilling would occur at night, so that lighting on drill rigs would be visible from residences with a direct line-of-sight to well sites. During the construction period, these activities would detract from the visual quality of the landscape and could conflict with residential and recreational uses, because they would be visually and audibly intrusive to residents and visitors. However, construction would be spread over the 10-year construction phase. The visual intrusion of these activities would be site specific and would not affect viewers outside of the viewshed of each construction site in the Project Area. The effects to the existing landscape from drilling are site spe-

273

cific and would occur at specific locations for no more than 3 days per drill site throughout the 10-year drilling period. The total disturbance associated with construction would not all occur at the same time within the overall 10-year construction phase. Some sites would be reclaimed back to the long-term disturbance areas before construction at other sites.

Drilling would be accomplished using drilling rigs, water trucks, backhoes, graders, or dozers and well servicing equipment. During a period of 1 to 3 days, these activities would detract from the visual quality of the landscape at each drill location. Once each well is completed, all disturbed areas that are not needed for production facilities would be restored. The mud pit would be dried and backfilled. These areas would be seeded as soon as practicable.

In addition to the disturbances created by construction on the sites, traffic would be associated with moving equipment over public highways and local roads. Trucks would be used to transport drilling components, auxiliary components, and personnel to each well site.

Construction would be evident to people using roads within the Project Area. Residents and visitors in the Project Area would be affected by the sight, dust, and noise of construction activities. In addition, the transport of equipment and materials to the Project Area would be evident to other travelers on local highways that would be used to access well sites.

Long-term Disturbance

The Proposed Action would constitute a change in the visual character of the existing rural landscape that characterizes most of the Project Area. The addition of well sites and associated access roads and power lines would result in a mixed rural/industrial landscape. The components with the highest potential to adversely affect the visual character of the area are the well pad clearings, pumping units, power lines, and access roads. Operation of the proposed facilities would introduce new elements of form, line, color, and texture into the landscape, and would essentially dominate foreground views and be obvious in middle ground and background views.

Long-term effects over the life of the project would result from the addition of the wells to the landscape and the disturbance of land used for associated facilities, such as power lines, water handling facilities, and compressor stations. The most visible components of the proposed facilities are expected to be the clearings for well pads and access roads, wellhead facilities, CMFs, water handling facilities, and compressor stations within the Project Area. CBM development is expected to modify the visual character of the existing rural landscape in the affected sub-watersheds where previously little or no oil and gas development had occurred. Proposed activities would not change the rural and industrial character of the landscape near Gillette and along segments of highways in the Project Area, which currently includes considerable modification from other oil and gas operations and from coal mining.

Most existing oil and gas development occurs in the Little Powder, Upper Belle Fourche, and Upper Powder River sub-watersheds in the general vicinity of Gillette. The landscape in this portion of the Project Area is characterized by oil and gas development in 80- to 160-acre well spacing patterns. Additional CBM development in these three sub-watersheds would increase the areal extent of the industrial components of the rural and industrial landscape. However, the overall landscape character in this area would remain similar to the existing landscape.

After well productivity is established, production facilities would include a weatherproof box structure installed over the wellhead and a metal fence or rail that encircles the box and electrical panel to protect them from livestock. There would be no pump jacks or other facilities at the wellheads. The facilities would be painted in non-reflective colors that harmonize with the surrounding landscape. The well pads would be 0.1 to 0.3 acres in size, depending on the number of wells located on the pads. Production facilities would be visible primarily in the foreground distance zone of about 0.5 miles or less from any viewing area. In the foreground and middleground to background distance zones (or more that 0.5 miles from a viewing area), the facilities would blend with the existing colors of the surrounding environment. The well pad clearings and access road disturbances would be visible in all zones as a result of contrasts in color and texture with the surrounding vegetation. The collocating of wells on a well pad minimizes the overall effect to the landscape by reducing the number of well pad clearings required for production facilities.

The largest effects would be to residential areas and isolated residences in the Upper Powder, Upper Belle Fourche, Clear Creek, Little Powder, Antelope, and Upper Tongue River sub-watersheds, particularly in those sub-watersheds in the general vicinity of Gillette. Several well pads that contain one or more wells would be adjacent to or within foreground distance zones of up to a mile from residences in some subdivisions located adjacent to Gillette municipal boundaries. Visible features would consist of well production facilities, well pad clearings, and access roads. Facilities would be most visible to travelers on affected highways during the time when they are within the line of sight as they travel toward the facility.

Approximately 10,619 miles of two-track roads and 7,135 miles of improved roads would be constructed to access proposed facilities from highways and local roads in the Project Area. Two-track roads would be used to access CBM wells in many cases because the need to travel to CBM wells is limited. Two-track roads represent a visible disturbance on the ground surface; however, as no surfacing is required, the visible disturbance from a two-track road is considerably less than is required for improved access roads. Improved roads would be constructed for some areas in rugged terrain and for non-CBM operations. Improved roads require a greater area of disturbance per mile of road and provide a greater degree of contrast between the road and the surrounding vegetation than do two-track roads. Access roads would be visible primarily in the foreground zones. The visual impact of each road can be lessened by aligning the road with the contours of the topography instead of cutting across the contours to the well pad, particularly on slopes. However, this method of aligning the roads may result in a greater area of disturbance. All roads constructed for the project would be removed and reclaimed, unless specifically requested by the landowner or county.

The gas-gathering and water-gathering pipelines would be buried adjacent to existing and new road ROWs. The combined ROW of each road and pipeline would vary according to the type of pipeline installed. Installation of the pipeline would avoid trees, where practicable, and brush and woody vegetation would be left in place and driven over so that they are potentially capable of redeveloping a vegetative canopy. Reclamation would begin immediately after the pipeline is buried. There would be no long-term effects to the landscape once pipelines are installed and reclaimed.

Aboveground electric distribution lines would connect wells and compressor stations with the existing transmission and distribution system within the Project Area. Electricity would be routed to facilities along the access roads or on additional ROWs (30 feet wide) across open land. Construction of power lines would occur after access roads are developed and would coincide within the end of well drilling. Power lines typically would be installed on 35-foot poles, which would be required every 300 feet. Approximately 5,311 miles of aboveground power lines would be installed in the Project Area. The pole structures would introduce straight, vertical lines and color contrasts. The effects from the introduction of these elements into the landscape can be noticeable if they are viewed from sensitive viewpoints when structures are visible in scenic landscapes and when structures are skylined.

Each compressor station would be lit at night with 250-watt, clear lights. Each light would be mounted on a pole or building and directed downward to illuminate the facility while minimizing the amount of light projected outside the facility. This type of night lighting would minimize the night shine from each facility. However, the stations would be visible at night to residents in nearby residential areas, isolated residences, or travelers on highways and local roads.

Produced water from CBM wells would be discharged by four methods: surface discharge at outfalls, containment in large upland evaporation reservoirs, spread on the land surface at LAD sites, or injected at an injection well facility site. The proposed water handling methods would disturb a total of 27,009 acres of surface land. Nearly 40 percent of the disturbance would occur from infiltration impoundments (37.1 percent). Water disposal at infiltration impoundments, containment reservoirs, or LADs would result in modifications to the surrounding landscape at the disposal sites. Surface discharge in some areas may cause a red surface staining where water is retained at the discharge point long enough for oxidation of iron to occur before discharge. The impact to the landscape would be limited in areas where these conditions would occur.

Each infiltration impoundment would consist of a shallow impoundment that would encompass an average of 6 acres, with an average dam height of 15 feet. Impoundments would be located in upland and bottomland areas. A total of 14,566 acres would be disturbed by infiltration impoundments, primarily in the Upper Powder River, Upper Cheyenne River, Crazy Woman Creek, and Upper Tongue River sub-watersheds. The majority of these areas are inventoried with VRM Class IV. The sites would have a low profile and would not be easily visible in the middleground and background zones from viewpoints at similar or lower elevations. The average 15-foot height of the dams would be the most visible feature of the impoundments, as the top of each dam would appear as a horizontal, linear form that would contrast with the natural terrain. Evaporation atomizers would be placed on towers that are likely not more than 40 feet in height, and would appear as a weak vertical contrast with the surrounding terrain. The spray from atomizers would be visible in foreground distance zones, but would be indistinct in middleground to background zones. Infiltration impoundments would be obvious in the foreground zone as seen from nearby roads and residences. Setting the impoundments back from roads, leaving a buffer zone of topography and vegetation, would mitigate the visual intrusion.

LAD sites would contain all water discharged over the life of 40 wells, affecting 1,780 acres of land surface (6.6 percent of total acres disturbed by water handling methods) in the Project Area. Each LAD site would be made up of four 16-acre LAD areas. The LAD sites would be located in relatively flat terrain to minimize off-site drainage and earth moving. The sites would have a low profile and would not be easily visible in the middleground and background zones from viewpoints at similar or lower elevations. The evaporation atomizers placed on towers would constitute a weak linear visual intrusion. LAD sites would be obvious in the foreground zone as seen from nearby roads and residences. Setting the LAD sites back from roads, leaving a buffer zone of topography and vegetation, can mitigate the visual intrusion. LAD sites would be located near containment reservoirs, which would provide temporary storage for those periods when the LAD site is not operational. In addition, the reservoirs would store water intended for LAD applications. The water disposed of at LAD sites is of a quality not suitable for surface discharge. Land application of this water would result in modifications to the existing vegetation, providing some contrast with existing vegetation.

The proposed containment reservoirs would affect 2,247 acres. The average disturbed area for each reservoir would be 100 acres. The disturbed area is comprised of the surface area of each reservoir, the dam, and diversion ditches. Reservoirs would be constructed in upland areas, away from drainages, floodplains, and gravelly terraces. These areas are generally outside of the viewsheds of most transportation routes and communities in the Project Area. In general, the upland locations of reservoirs could result in additional disturbances from earth moving and extensive diversion ditches. LAD sites that would be located near reservoirs in upland areas would also require more earth moving than those located in flatter terrain, resulting in greater disturbances to the character of the landscape.

BLM Lands

A total of 5,600 CBM wells distributed on 3,447 well pads are proposed for BLM surface ownership in the Project Area, accounting for 14.2 percent of the 39,367 new CBM wells proposed for the Project Area. The BLM has inventoried all lands within the Project Area with the VRM system. However, only lands administered by the BLM are managed with VRM objectives. Although proposed CBM wells on state, private, and Forest Service lands are not managed for BLM's VRM objectives, the inventory provides an assessment of the existing scenic quality and the ability of these lands to absorb effects to the landscape from development.

Table 4–67 summarizes all proposed CBM wells in the Project Area proposed for Alternative 1 by sub-watershed and VRM Class inventory. The disturbance acres

Table 4–67 Proposed Wells and Well Pads in VRM Classes by Sub-watershed in the Powder River Basin Project Area

	Class II			Class III			Class IV			Class V			Total		
Sub-Watershed	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed Wells	Proposed Pads	Term Pad Disturbance (acres)
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	160	54	103	352	193	441	2,077	892	2,060	0	0	0	2,589	1,139	2,603
Middle Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	785	448	758	2,636	1,461	2,259	15,546	9,933	16,385	0	0	0	18,967	11,842	19,403
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	37	37	378	0	0	0	37	37	378
Crazy Woman Creek	0	0	0	411	397	870	2,509	1,501	3,082	0	0	0	2,920	1,898	3,952
Clear Creek	192	185	246	898	539	1,015	2,663	1,860	2,870	0	0	0	3,753	2,584	4,132
Middle Powder River	0	0	0	0	0	0	958	465	1,072	0	0	0	958	465	1,072
Little Powder River	0	0	0	25	18	55	1,810	1,077	3,754	200	170	556	2,035	1,265	4,365
Little Missouri River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antelope Creek	0	0	0	91	83	746	1,553	1,368	12,673	0	0	0	1,644	1,451	13,420
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cheyenne River	0	0	0	0	0	0	487	487	992	46	46	139	533	533	1,131
Lightning Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Belle Fourche River	0	0	0	751	644	1,144	5,046	4,005	6,726	134	134	190	5,931	4,783	8,060
Middle North Platte Casper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1,137	687	1,107	5,164	3,335	6,532	32,686	0	49,992	380	350	885	39,367	25,997	58,516

Note: Disturbance acres for well pads include the disturbance associated with ancillary facilities such as roads, compressors, and transmission lines. Totals may not match precisely with values obtained by adding unit numbers or with distributions of pads and wells presented in Chapter 2 due to rounding conventions.

BEST COPY AVAILABLE

BLANK PAGE

for well pads include the disturbance associated with ancillary facilities connected to the pads, such as roads, pipelines, and power lines. Water handling facilities, such as LADs and containment reservoirs, may be located on BLM lands, but specific locations by VRM Class are unknown.

There are 4,515 wells distributed on 2,854 well pads and 43 compressors proposed for BLM lands managed with VRM Class IV objectives. Most of the remaining wells and compressors are located on private lands, and a small number are on state and Forest System lands. Lands inventoried with VRM Class IV account for most lands within the Project Area. Most CBM wells proposed for these lands are within the Upper Powder River sub-watershed. Class IV objectives provide for major modification to the landscape and allow management activities to dominate the landscape. Construction and operation of each well and the ancillary facilities would be consistent with VRM Class IV objectives. Consequently, none of the disturbed acreage would be displaced from the existing BLM inventory of lands managed with VRM Class IV. The proposed facility developments would be consistent with management objectives.

There are 766 wells distributed on 416 well pads and four compressor stations proposed for BLM lands managed with VRM Class III objectives. Class III lands in the Project Area are located primarily along major transportation routes and recreation areas. Class III objectives are to provide for management activities that may contrast with the basic landscape elements but remain subordinate to the existing landscape character. Implementation of this alternative along highways and in areas that are not currently developed with CBM wells would change the existing rural landscape to a rural and industrial landscape primarily because the 40- to 80-acre spacing of the wells would result in a noticeable density of industrial facilities. There is the potential that Class III objectives would not be met because the facilities would not be subordinate to the existing landscape character. BLM objectives for some Class III facilities would be met if every attempt were made to minimize adverse visual effects through careful location of facilities, minimal disturbance of the site, and painting facilities so they harmonize with the colors of the surrounding landscape.

There are 316 wells on 175 well pads and three compressor stations proposed for BLM lands managed with VRM Class II objectives. None of these wells would be in the Class II lands in the western part of the Project Area, at the base of the Big Horn Mountain. All 316 wells would be within the Class II areas along portions of Interstate 90 and State Highway 14.

The VRM Class II objective is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low and not attract the attention of the casual observer. Many of the CBM wells on BLM lands would be visible to travelers on Interstate 90 and State Highway 14. All of the wells proposed for these areas are within the foreground distance zone (up to 3 miles) of the viewshed as seen from the highways. The Proposed Action would change the existing rural landscape to a rural and industrial landscape primarily because the 40- to 80-acre spacing of the wells would result in a noticeable density of industrial facilities. The Class II objectives would be met if mitigation measures were used to maintain the existing character of the landscape, and not attract the attention of the casual observer. Mitigation measures must repeat the basic elements of form, line, color, and texture found in the natural features of the landscape within the foreground distance zone to achieve this objective. Successful mitigation in the foreground distance zone would include locating facilities to use the terrain and vegetation to screen them from the highways. If the mitigation measures would not enable facilities to meet Class II objectives, one of the following two options must be implemented to comply with BLM management objectives: (1) the facilities would be relocated to a site outside of the VRM Class II area on BLM lands; or (2) the BLM RMP would be amended to change the affected VRM Class II areas to VRM Class III areas.

Three CBM wells on two well pads and no compressor stations are proposed for BLM lands inventoried with VRM Class V. The proposed facilities on BLM lands would be consistent with BLM management objectives for VRM Class V areas, which provide for areas where the natural character has been drastically altered.

The Buffalo Field Office has developed a management decision to implement the management objective of maintaining or improving scenic values, visual quality, and establish visual resource management priorities in conjunction with other resource values. Visual resources are to be managed in accordance with objectives for VRM classes that have been assigned to the planning area, which constitutes most of the Project Area. No activity or occupancy is allowed within 200 feet of the edge of state and federal highways. Facilities or structures such as power lines, oil wells, and storage tanks are required to be screened, painted, and designed to blend with the surrounding landscape except where safety indicates otherwise. Any facilities or structures proposed in or near WSAs would be designed so as not to impair suitability as wilderness.

BLM lands in the Fortification Creek WSA and the Fortification Creek SMA are inventoried with VRM Class III. An NSO for mineral development has been stipulated for the WSA. A CSU has been stipulated for the Fortification Creek SMA, which encompasses the WSA, to protect scenic values. Proposed facilities in the SMA must meet Class III objectives to protect scenic values. There is potential that Class III objectives would not be met because the facilities would not be subordinate to the existing landscape character. BLM objectives for some Class III facilities would be met if every attempt were made to minimize adverse visual effects through careful location of facilities, minimal disturbance of the site, and painting facilities so they harmonize with the colors of the surrounding landscape. No facilities are proposed for the WSA because of the NSO.

The Cantonment Reno and Weston Hills Recreation Area are inventoried with VRM Class IV. No project facilities are proposed for location within these two SMAs. Indirect effects to recreational uses of the SMAs would occur because landscapes outside of these areas would be modified by the addition of project facilities, which would affect the recreational experience of visitors to the SMAs. CBM wells proposed for lands adjacent to the Cantonment Reno and Weston Hill Recreation Area would be visible to viewers in the areas. BLM Class IV objectives for the SMAs and adjacent lands would be met.Long-term visual effects would be minimized by designing permanent structures to harmonize with the surrounding landscape to the extent feasible, recontouring and revegetating disturbed areas that are no longer needed for operations as soon as practicable, and by reshaping straight edges of clearings resulting from roads, pipelines, well pads, and compression facilities to create irregular or indistinct edges. Construction debris would be removed immediately because it creates undesirable textural contrasts with the landscape. When they are installed on ridgelines, atomizers may be visible for 20 miles or more, depending on the weather conditions. In addition, resource protection measures proposed for erosion control, road construction, rehabilitation and revegetation, and wildlife protection would be implemented APDs and Sundry Notices are approved. These measures also would mitigate effects to visual quality. Visual resource protection measures would be implemented in cooperation with the surface owner for surface lands with split mineral estate.

Forest Service (Thunder Basin National Grassland)

There would be 369 wells distributed on 332 well pads proposed for federal lands administered by the Medicine Bow National Forest within the Thunder Basin National Grassland. Most of the federal lands on that portion of the TBNG that is within the Project Area are managed with the SIO of Low. A small portion of the TBNG within the Project Area is managed with the SIO of Moderate. The TBNG lands managed with Moderate SIO are along Antelope Creek or are in an area outside of the boundary of the coal. No wells are proposed for TBNG lands managed with the SIO of Moderate. All of the proposed 369 wells are on TBNG lands managed with the Low SIO.

Scenery management guidelines for the TBNG are to manage activities to be consistent with the SIOs and to rehabilitate areas that do not meet the SIOs specified for the management area. Visual management objectives for SIOs are associated with desired landscape character for each management area and are based on the intent of the management area direction. Facilities are proposed for three of the seven management areas within the Project Area. Facilities are not managed with goals for a desired condition for scenic values in Management Areas 3.68 (Big Game Range) and 6.1 (Rangeland with Broad Resource Emphasis). The SIO for these areas is Low. Few facilities are proposed for these areas. The majority of wells and ancillary facilities are proposed for Management Area 8.4 (Mineral Production and Development). The desired condition for landscapes in this management area is that facilities and landscape modifications can be visible, but are reasonably mitigated to blend and harmonize with natural features.

State and Private Lands

There are 2,620 wells distributed on 1,660 well pads and seven compressor stations proposed for state lands in the Project Area. Mineral leases administered by the Wyoming Office of State Lands and Investments do not include guidance on the management of visual or scenic resources on state-owned lands in the Project Area. According to rules and regulations of the Board of Land Commissioners, all related disturbances must be reclaimed to leave the land in as near as practicable to the original condition before operations when operations are complete on state lands.

Most of the proposed facilities would be located on private lands. There are 30,778 wells (78.2 percent of total proposed wells) distributed on 20,558 well pads (79.1 percent of proposed well pads) and 183 compressor stations (75 percent of total number of compressor stations) proposed for private lands in the Project Area. The majority of effects to the landscape would occur on private land because most wells are located on private land and most of the land within the viewsheds of communities, rural residential areas, and transportation routes is private land.

Counties

The Sheridan County Growth Management Plan identifies the need for an inventory of existing resources, including scenic resources, and use of this information in reviewing and evaluating proposed developments. Currently, no procedure or ordinance exists that provides for evaluation and review.

The Comprehensive Planning Program jointly developed by the City of Gillette and Campbell County recommends that landscaping should be developed into the buffer zones where industrial areas are located adjacent to residential areas. There are numerous CBM wells proposed for lands adjacent to residential areas in subdivisions located outside of the Gillette municipal boundaries.

Non-CBM Development

The moderate level of conventional oil and gas development as evaluated under the BLM's RFD scenario projects that 3,000 non-CBM wells will be drilled and completed within the Buffalo Field Office's portion of the Project Area over the 10-year period. Surface disturbances required for conventional wells are greater than are required for the new CBM wells, as described earlier in this section. Short-term surface disturbances for well pads and associated improved access roads range from 0.5 acres for shallow gas wells to 5.5 acres for a typical deep oil well. Long-term disturbances would encompass about 82 percent of the original disturbance.

Non-CBM facilities consist of pump jacks, in contrast with CBM facilities, which consist of a wellhead contained in a metal box. The components with the highest potential to impair the character of the surrounding landscape are the well pad clearings, the improved access roads, and the pump jacks. Operation of the proposed facilities would introduce new elements of form, line, color, and texture into the landscape; would essentially dominate foreground views; and would be obvious in middleground and background views. Effects would be similar to CBM well facilities; however, each well pad and associated access road would disturb a larger number of acres.

The alignment of individual pump jacks with respect to viewing areas, such as residential areas, individual residences, and transportation routes, should be reviewed during the pre-installation phase of well development. In general, each pump jack should be aligned parallel to a road unless it has been determined that this alignment is not feasible. Facilities would be the most visible to travelers on the road during the period when the facility is within the line of sight as they travel toward the facility. Aligning pump jacks parallel to roads would present travelers with a smaller surface area as the traveler approaches the facility. In addition, pump jacks with the lowest possible profile should be used when feasible.

Alternative 2

Alternative 2 differs from Alternative 1 in the distribution of produced water among the methods for handling produced water and the compression of gas. Alternative 2A emphasizes use of infiltration impoundments to dispose of produced water, while Alternative 2B emphasizes use of passive and active treatments. The number and distribution of CBM and non-CBM conventional wells is the same as were evaluated for Alternative 1. The impacts to the characteristic landscape from the development of CBM wells and the ancillary facilities other than facilities for handling produced water are identical to Alternative 1.

Alternative 2A or Alternative 2B would result in the disturbance of more surface acres (36,264 acres under Alternative 2A and 32,653 acres under Alternative 2B) than Alternatives 1 or 3. For both Alternatives 2A and 2B, the largest disturbances would occur from infiltration impoundments (23,799 acres under Alternative 2A and 16,694 acres under Alternative 2B). The operation of infiltration impoundments under Alternative 2A would affect 138 percent more surface land that impoundments proposed for Alternative 1. Alternative 2B would affect 67 percent more surface land that Alternative 1. The impact to the visual quality of the landscape is substantially larger from Alternatives 2A or 2B than for the proposed Alternative 1. The impoundments would be located outside of transportation corridor and residential area viewsheds and would primarily affect lands inventoried with VRM Class IV.

LAD sites would affect 4,337 acres of land in the Project Area under Alternative 2A, an increase of 144 percent over the LAD sites proposed for the Proposed Action. The containment reservoirs would affect 3,365 acres under Alternative 2A or 1,069 acres under Alternative 2B. Alternative 2A would be a decrease of 7.9 percent from the Proposed Action, primarily within VRM Class IV areas. Alternative 2B would be a decrease of 35 percent from the Proposed Action. The increase in LAD sites over the Proposed Action would result in larger areas of modified vegetation as described for the Proposed Action. Under Alternative 2B, LAD sites would affect 4,570 acres, an increase of 157 percent over Alternative 1. The number of acres disturbed by containment reservoirs would not be substantially different from the Proposed Action and would result in a similar level of visual impact. The effects of injection wells and surface discharge to the landscape would be minor. The acreages that would be affected from these water-handling methods proposed for Alternative 2A or Alternative 2B are considerably greater than the total 27,009 acres that would be affected under the Proposed Action.

Alternative 3

Under the No Action alternative, there would be no CBM development on federal leases within the Project Area. Federal leases are located on private as well as federal lands. Development would continue on state and private leases. A total of 15,504 CBM wells would be developed on state and fee leases. The No Action alternative includes all of the effects to visual resources described for Alternative 1, but differs from Alternative 1 in the number of wells to be developed, the acres of land to be disturbed temporarily or removed from existing uses during the life of the project, and the volume of water to be produced from CBM wells. The effects to the characteristic landscape from the No Action alternative would considerably less than are described for the Proposed Action because 15,504 CBM wells proposed for state and fee mineral leases is 39 percent of the total 39,367 new CBM wells under the Proposed Action. Table 4–68 summarizes the long-term disturbance by VRM Class for each sub-watershed. Although proposed CBM wells on state and fee lands are not managed for BLM's VRM objectives, the inventory provides an assessment of the existing scenic quality and the ability of these lands to absorb effects to the landscape from development.

Because fewer wells are proposed for the Project Area, a considerably smaller number of facilities also would be proposed for the distribution of produced water under the No Action alternative. LAD sites would affect 808 acres of land in the Project Area, a decrease of 55 percent from the LAD sites proposed for the Alternative 1. The containment reservoirs would affect 1,690 acres, a decrease of 67 percent from Alternative 1. The effects of injection wells and surface discharge to the landscape would be minor. A total of 11,683 acres would be affected from all water-handling methods proposed for this alternative, which is about 57 percent less than the total 27,009 acres that would be affected under the Alternative 1.

Cumulative Effects

The cumulative well development scenario is represented by the 39,367 CBM wells under the Proposed Action and 12,077 CBM wells already drilled or permitted within the Project Area. The non-CBM cumulative scenario includes 2,546 existing wells and 3,200 new wells. Tables 4–69, 4–70, and 4–71 summarize the long-term disturbance by VRM Class for cumulative CBM, compressors, and non-CBM wells in each sub-watershed.

The cumulative effect on the landscape would consist of existing, permitted, and proposed CBM development on federal, state, and private lands in the Project Area, and existing, proposed, and reasonably foreseeable coal mining in the Project Area. The cumulative effect of all existing and proposed development would result in a larger number of disturbed acres from well pads and access roads that may be visible from transportation routes and recreation areas. Ongoing CBM development on federal, state, and private lands would increase the industrial character of those areas that include considerable modification from other oil and gas development and from coal mining, and change the visual character of the predominantly rural landscape in much of the Project Area to rural/industrial.

A principal visual effect in the eastern part of the Project Area and near the city of Sheridan is the visibility of coal mine pits and facility areas. However, anyone likely to see these facilities would either be passing through the area or visiting on related business. After mining ends, the reclaimed slopes might appear some what smoother than pre-mining slopes and there would be fewer gullies than at present. Even so, the landscape of the reclaimed mines would look very much like undisturbed landscape in the area. Except from the air, energy development, including CBM, are not visible from more than a few miles away.

BLANK PAGE

Table 4–68 Alternative 3 Wells and Well Pads in VRM Classes by Sub-Watershed in the Powder River Basin Project Area

	Class II			Class III			Class IV			Class V			Total		
Sub-watershed	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Proposed CBM Wells	Proposed Pads	Long Term Pad Disturbance (acres)	Total Proposed Wells	Proposed Pads	Long Term Pad Disturbance (acres)
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	130	44	83	346	190	339	1,688	746	1,364	0	0	0	2,164	980	1,786
Middle Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	146	93	115	662	391	487	3,637	2,363	2,906	0	0	0	4,445	2,847	3,508
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	19	19	160	0	0	0	19	19	160
Crazy Woman Creek	0	0	0	183	183	296	766	455	768	0	0	0	949	638	1,065
Clear Creek	120	114	152	839	505	704	1,543	1,126	1,537	0	0	0	2,502	1,745	2,393
Middle Powder River	0	0	0	0	0	0	201	97	158	0	0	0	201	97	158
Little Powder River	0	0	0	14	9	28	805	512	1,579	145	134	407	964	655	2,013
Little Missouri River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antelope Creek	0	0	0	40	32	288	564	495	4,453	0	0	0	604	527	4,742
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cheyenne River	0	0	0	0	0	0	232	232	276	24	24	29	256	256	305
Lightning Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Belle Fourche River	0	0	0	574	502	719	2,705	2,185	3,148	121	121	171	3,400	2,808	4,038
Middle North Platte Casper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	396	251	350	2,658	1,812	2,861	12,160	8,230	16,350	290	279	607	15,504	10,572	20,167

Table 4-69 CBM Cumulative and Well Pads in VRM Classes by Sub-Watershed in the Powder River Basin Project Area

	Class II			Class III			Class IV			Class V			Total		
Sub-watershed	Proposed & Existing CBM Wells	CBM Pads Existing and Proposed	Long Term Pad Disturbance (acres)	Proposed & Existing CBM Wells	CBM Pads Existing and Proposed	Long Term Pad Disturbance (acres)	Proposed & Existing CBM Wells	CBM Pads Existing and Proposed	Long Term Pad Disturbance (acres)	Proposed & Existing CBM Wells	CBM Pads Existing and Proposed	Long Term Pad Disturbance (acres)	Proposed & Existing CBM Wells	CBM Pads Existing and Proposed Total	Long Term Pad Disturbance (acres)
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	489	190	353	438	248	538	2,481	1,098	2,430	0	0	0	3,408	1,536	3,321
Middle Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	966	581	919	2,825	1,623	2,453	17,984	11,892	18,737	0	0	0	21,775	14,096	22,109
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	37	37	378	0	0	0	37	37	378
Crazy Woman Creek	0	0	0	537	443	952	2,533	1,518	3,110	0	0	0	3,070	1,961	4,063
Clear Creek	204	192	257	1,131	677	1,216	2,807	1,946	2,995	0	0	0	4,142	2,815	4,467
Middle Powder River	0	0	0	0	0	0	1,685	903	1,766	0	0	0	1,685	903	1,766
Little Powder River	0	0	0	38	31	95	3,374	2,175	7,123	437	360	1,136	3,849	2,566	8,353
Little Missouri River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antelope Creek	0	0	0	92	84	755	1,803	1,616	14,901	0	0	0	1,895	1,700	15,657
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cheyenne River	0	0	0	0	0	0	871	861	1,438	63	62	158	934	923	1,596
Lightning Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Belle Fourche River	0	0	0	1,259	1,134	1,841	9,160	7,745	12,063	171	170	241	10,590	9,049	14,145
Middle North Platte Casper	0	0	0	0	0	0	6	6	54	0	0	0	6	6	54
Total	1,659	963	1,529	6,320	4,240	7,849	42,741	29,797	64,995	671	592	1,535	51,391	35,592	75,908

BEST COPY AVAILABLE

286

Table 4–70 Non-CBM Cumulative and Well Pads in VRM Classes by Sub-Watershed in the Powder River Basin

	Class II		Class III		Class IV		Class V		Total	
Sub-watershed	Proposed & Existing Non-CBM Wells	Long Term Pad Disturbance (acres)	Proposed & Existing Non-CBM Wells	Long Term Pad Disturbance (acres)	Proposed & Existing Non-CBM Wells	Long Term Pad Disturbance (acres)	Proposed & Existing Non-CBM Wells	Long Term Pad Disturbance (acres)	Proposed & Existing Non-CBM Wells	Long Term Pad Disturbance (acres)
Little Bighorn River	3	7	2	5	0	0	0	0	5	12
Upper Tongue River	9	21	16	38	24	56	1	2	50	118
Middle Fork Powder River	12	28	20	47	18	42	1	2	51	120
North Fork Powder River	1	2	0	0	0	0	0	0	1	2
Upper Powder River	17	40	88	207	780	1,833	0	0	885	2,080
South Fork Powder River	0	0	0	0	29	68	0	0	29	68
Salt Creek	0	0	0	0	71	167	0	0	71	167
Crazy Woman Creek	0	0	3	7	13	31	0	0	16	38
Clear Creek	3	7	7	16	18	42	0	0	28	66
Middle Powder River	0	0	0	0	163	383	0	0	163	383
Little Powder River	0	0	332	780	1,590	3,736	14	33	1,936	4,550
Little Missouri River	0	0	0	0	109	256	0	0	109	256
Antelope Creek	0	0	6	14	352	827	0	0	358	841
Dry Fork Cheyenne River	0	0	6	14	154	362	0	0	160	376
Upper Cheyenne River	0	0	0	0	111	261	19	45	130	306
Lightning Creek	0	0	75	176	354	832	0	0	429	1,008
Upper Belle Fourche River	42	99	208	489	973	2,287	56	132	1,279	3,006
Middle North Platte Casper	0	0	0	0	46	108	0	0	46	108
Total	87	204	763	1,793	4,805	11,292	91	214	5,746	13,503

Table 4–71 Proposed Compressors in VRM Classes by Sub-Watershed in the Powder River Basin Project Area

	Class II			Class III			Class IV			Class V			Total		
Sub-watershed	Proposed Booster Stations	Proposed Recip Stations	Long Term Pad Disturbance (acres)	Proposed Booster Stations	Proposed Recip Stations	Long Term Pad Disturbance (acres)	Proposed Booster Stations	Proposed Recip Stations	Long Term Pad Disturbance (acres)	Proposed Booster Stations	Proposed Recip Stations	Long Term Pad Disturbance (acres)	Proposed Booster Stations	Proposed Recip Stations	Long Term Pad Disturbance (acres)
Little Bighorn River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Tongue River	0	0	0	0	1	98	6	1	423	0	0	0	6	2	521
Middle Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Powder River	7	0	198	12	2	424	97	33	4,142	0	0	0	116	35	4,764
South Fork Powder River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	2	1	67	0	0	0	2	1	67
Crazy Woman Creek	0	0	0	3	2	226	9	3	551	0	0	0	12	5	777
Clear Creek	0	0	0	5	1	262	4	2	318	0	0	0	9	3	580
Middle Powder River	0	0	0	0	0	0	3	1	316	0	0	0	3	1	316
Little Powder River	0	0	0	0	0	0	5	3	421	1	0	39	6	3	460
Little Missouri River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antelope Creek	0	0	0	0	0	0	7	3	366	0	0	0	7	3	366
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cheyenne River	0	0	0	0	0	0	2	2	412	1	0	84	3	2	496
Lightning Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Belle Fourche River	0	0	0	4	1	221	16	5	947	0	0	0	20	6	1,168
Middle North Platte Casper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	7	0	198	24	7	1,231	151	54	7,964	2	0	123	184	61	9,516

BEST COPY AVAILABLE

BLANK PAGE

Recreational Resources

The potential effect of the construction and operation of the proposed facilities on recreational resources is related to the amount of recreational opportunity that is created by the project versus the opportunity that is lost for recreational pursuits. Local residents value the federal lands for recreation because of the proximity and the relative solitude that can be achieved within a short distance from their homes. The recreational issue identified in the scoping process is the effects of the additional development of oil and gas resources on recreational opportunities and the recreational experience.

Alternative 1

The Proposed Action would be constructed and operated on federal, state, and private lands. The primary effect of the CBM development on recreational opportunities would be the alteration of the experience on federal and state lands used for hunting. To some degree, additional development of oil and gas resources would alter the existing recreational setting and experience. The Project Area is predominantly rural in character, with some industrial-type modifications from existing wells.

Direct effects occur when recreational opportunities are enhanced, limited, or curtailed within an area; when recreational uses are created, displaced, or eliminated by proposed CBM facilities; or if federal, state, or county objectives for recreation cannot be met. Effects to recreational resources occur if recreational facilities undergo substantial change or degradation.

Direct effects to recreational uses in the Project Area would occur because additional wells would add new industrial features to the landscape and new sources of noise that could diminish the recreational experience and affect the rural ambience sought by recreationists. Construction and operation of the proposed facilities also could affect recreation by changing access opportunities and by directly disrupting recreational activities. New roads would provide access for vehicles and promote an increase in human activity. Additional development could adversely affect hunting, viewing of wildlife, and fishing. Development of certain facilities, such as reservoirs for impounding produced water, could enhance some wildlife-related recreational opportunities by providing areas for viewing wildlife, hunting waterfowl, or public fishing.

Indirect effects to recreation would occur if the project resulted in a change in the level of visitation to the area or would alter growth in the affected counties, thereby changing the use of existing recreational facilities and uses. No developed recreation sites would be directly affected by installation of the facilities proposed. However, visitation to these sites could temporarily increase during years of peak employment (2004 through 2011). Dispersed recreation such as hunting also may be affected on some public and private lands. The project is not expected to affect the level of visitation and population growth in the counties for most of the life of the project. It is anticipated that the existing workforce would be sufficient to provide adequate personnel for construction and operation of proposed CBM facilities for most of the life of the project; therefore, there would be minimal long-term growth in population from in-migration and minimal long-term increase in the demand for recreational opportunities. Peak employment would require up to 2,660 additional workers over the existing 2,943 workers. The majority of the workforce during peak employment would reside in the counties in the project area. It is anticipated that a small percentage of the peak workforce would come from outside the region. It is unknown, however, how many of these additional workers would be in-migrants, as discussed in the section on Socioeconomic Impacts.

The recreation and tourism industry in counties in the Project Area consists a variety of businesses that are part of the Service sector, including wholesale and retail trade, transportation, and other services. In addition, tourism depends on other factors such as the health of the national economy, consumer confidence, the price of airfare, and gasoline prices. Currently, the detailed information needed to isolate and analyze recreation and tourism does not exist for counties or communities in the Project Area. Subsectors of the Services economic sector include lodging places and amusement and recreation services. These subsectors are indicators of trends in recreation and tourism, although they include dollars spent by residents of the counties as well as by tourists. Earnings in the Amusement and Recreation Services sector have fluctuated in the decade between 1990 and 2000; however, the overall trend has remained steady, with earnings in the year 2000 slightly greater that 1990 earnings. Earnings in the lodging, amusement, and recreation sectors have not decreased as a result of increases in gas production, as shown in Figures 4-45, 4-46, and 4-47. Future earnings are likely to continue the trends shown for 1990 through 2000, as the increase is gas production, including CBM development, has not apparently affected earnings in these sectors.

Construction Disturbance

Short-term effects to recreation within the Project Area would result from all phases of the construction process. Activities associated with installation of the CBM wells, including construction of roads, pipelines, power lines, and other ancillary facilities, would alter the use of affected roads for the duration of construction. Construction can be expected to occur over a period of 10 years over the entire Project Area. It is anticipated that the annual construction period would be 7 days per week over the entire year, or 365 days, depending on weather and soil conditions. During this period, there would be disturbance to the existing landscape character, and noise and dust from construction. These activities could conflict with recreational uses because they would be visually and audibly apparent to the recreational experience. The effects to the existing land uses from drilling are site specific and would occur at specific locations for no more than 3 days per drill site throughout the 10-year drilling period. Some sites would be reclaimed back to the permanent disturbance areas before construction began at other sites.

In addition to the disturbances created by construction on the site, traffic would be associated with moving equipment over public highways and local roads. Traffic-related effects are evaluated in the section on Transportation. Access roads would be constructed to connect CBM facilities with highways and local roads. A total of 17,754 miles of improved roads and two-track roads would be constructed in the Project Area. Road construction is expected to average 1 day

BLANK PAGE

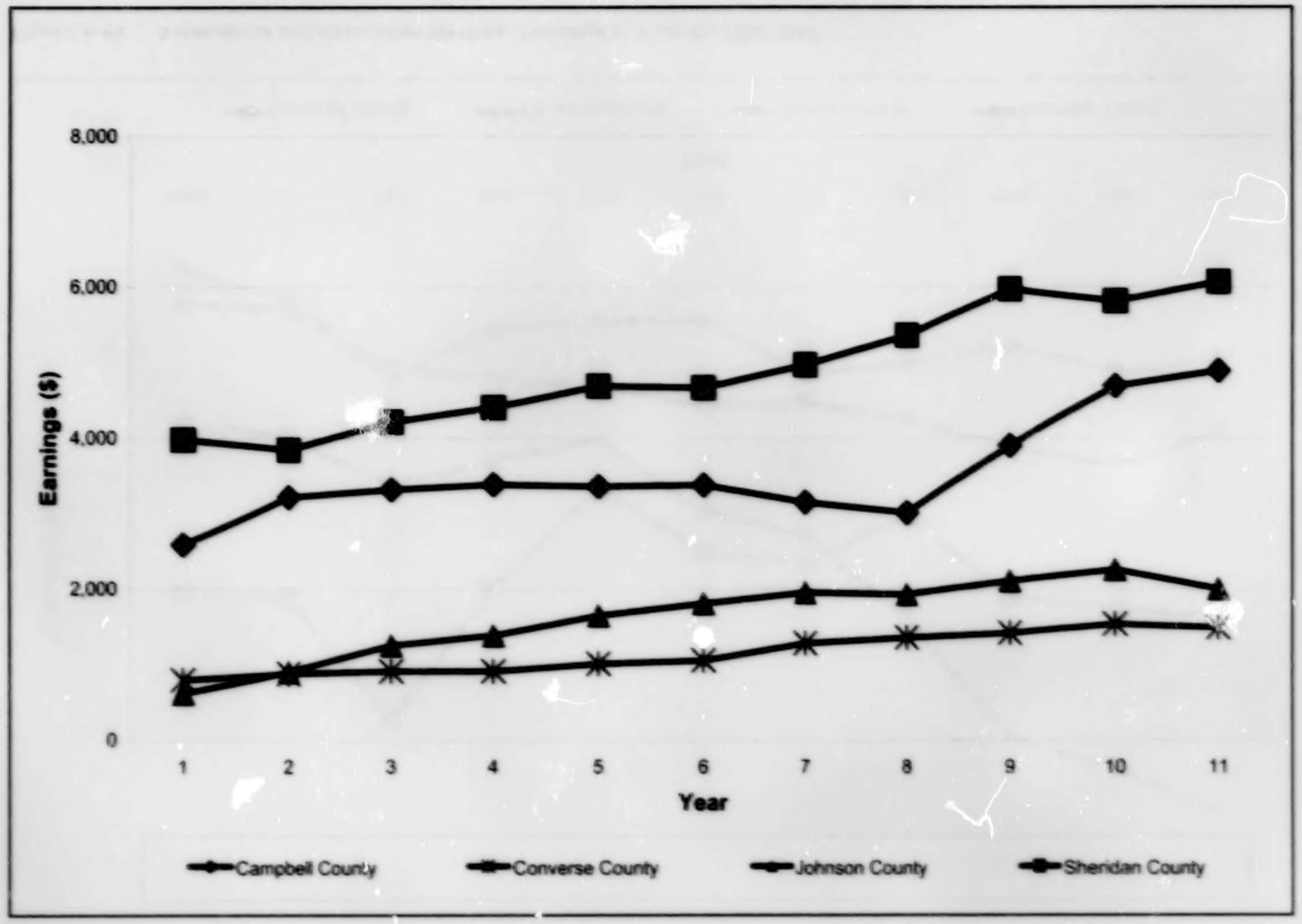


Figure 4–45 Hotels and other Lodging Services: Earnings by County, 1990–2000

291

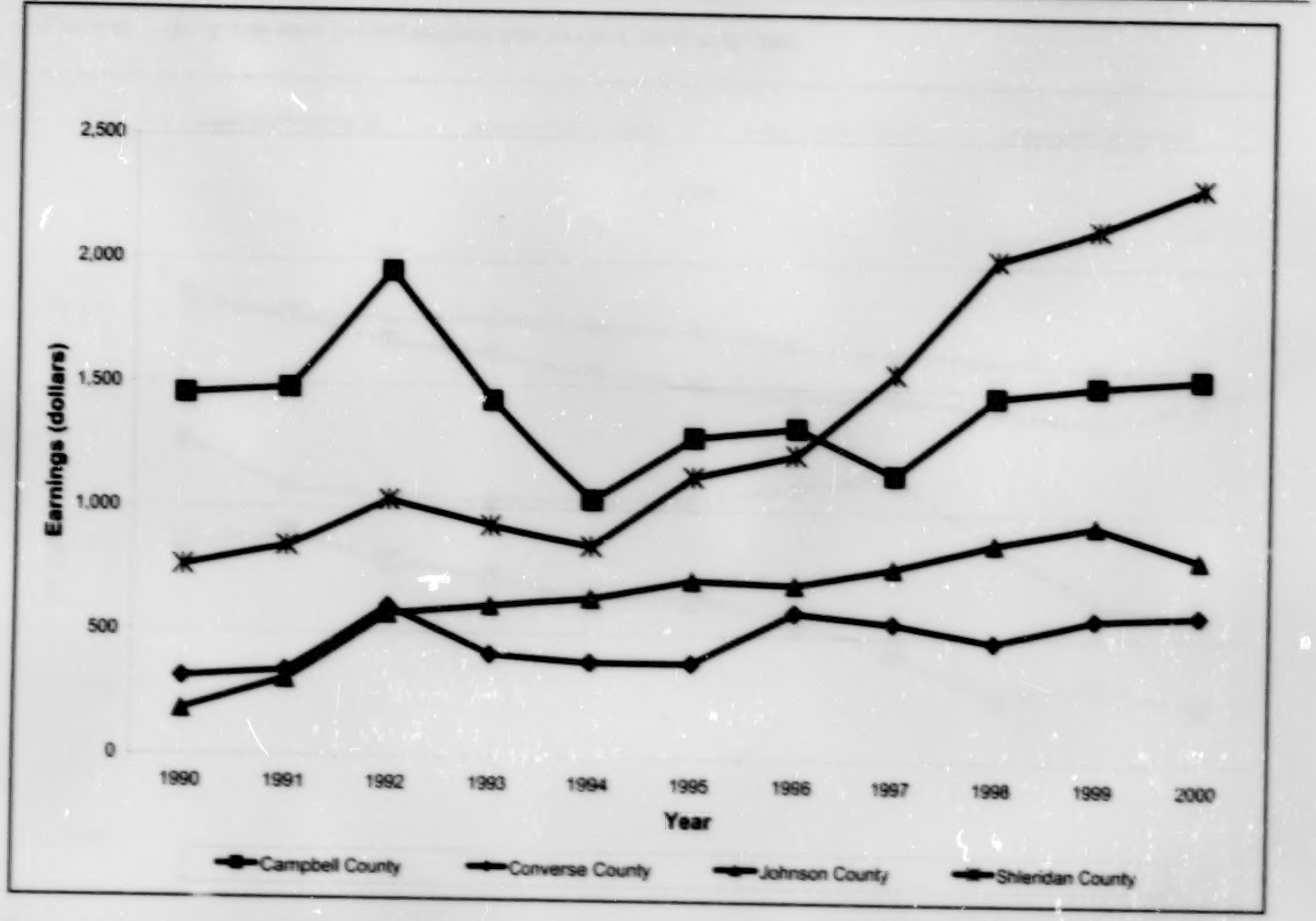


Figure 4-46 Amusement and Recreation Services: Earnings by County, 1990–2000

BLANK PAGE

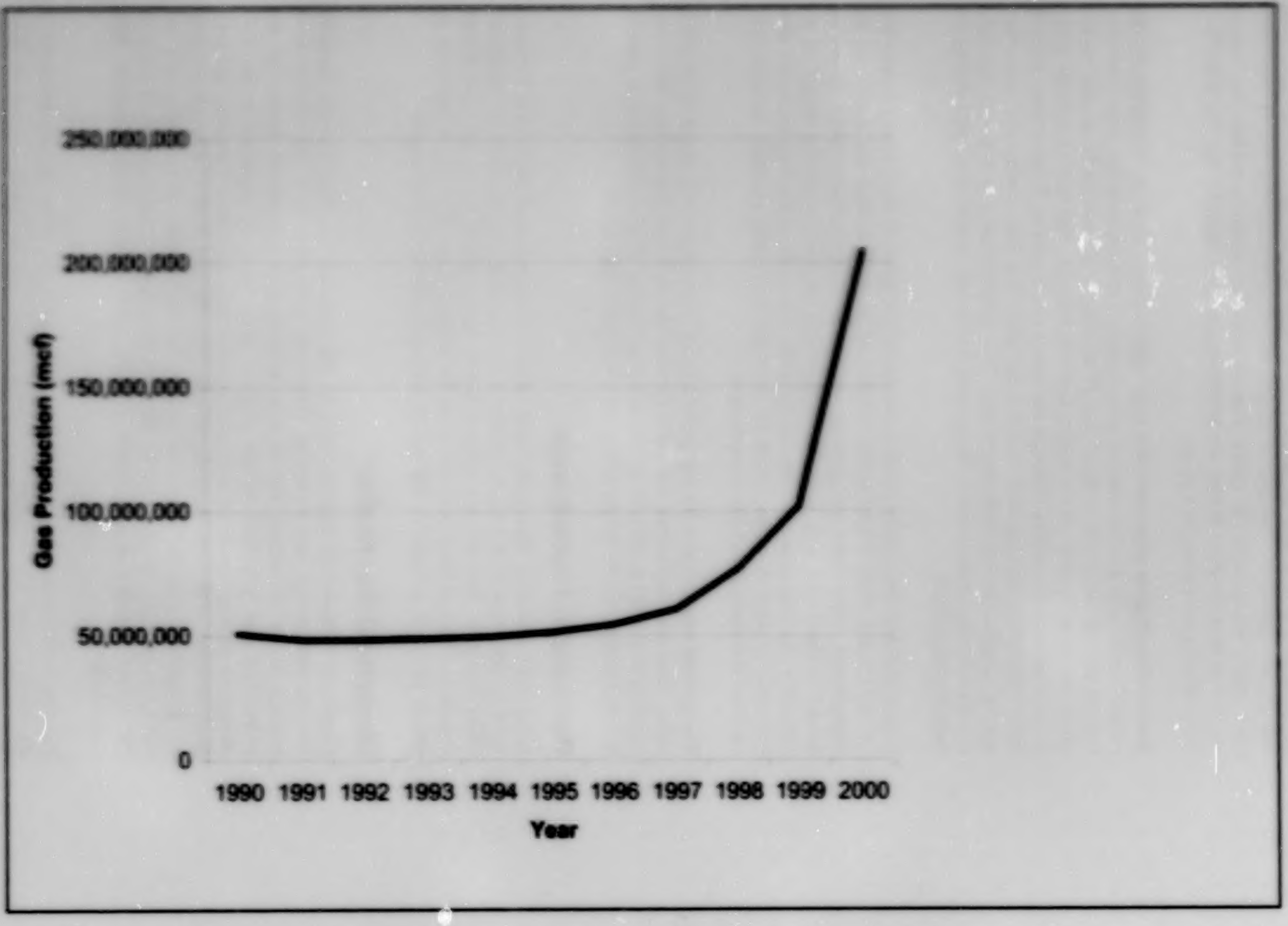


Figure 4–47 Gas Production in Campbell, Converse, Johnson, and Sheridan Counties, 1990–2000

per mile, or a total of approximately 17,754 days. Construction would occur over the 10-year period as required to access wells. Recreationists would encounter road construction over the entire year at specific locations within the Project Area. The loss of solitude and the natural experience would affect local users in the particular area of construction.

Pipeline installation along existing road rights-of-way is likely to inconvenience recreationists who use the roads to gain access to recreation in the area. Construction would also limit recreational use of existing roads and trails, as well as degrade the visual quality of the recreational experience. The loss of solitude along these roads would continue through the construction period. Road access is likely to be restored to existing uses within a few days to a few months after construction or installation has been completed. The recreational opportunities for local residents in close proximity to the proposed activities would be altered during the construction period.

Project construction would result in increased noise levels from heavy equipment in surrounding areas. Construction-related noise could reduce the quality of the recreational experience in general. However, construction-related increases would be short term and, with the exception of blasting, generally would be restricted to the immediate vicinity of the work. Noise from blasting would be sporadic and of short duration. There are potential long-term increases in noise levels from the operation of the compressors.

The general season dates for big game hunting (all types of big game in all units) occur from late September and early October through late November. The hunting season would be affected by construction for the 10-year construction period, but only at specific locations where construction is scheduled.

Permanent Disturbance

Long-term effects to developed and dispersed recreational uses of the Project Area would occur as the displacement of acreage from existing uses by proposed CBM facilities. The primary effects would be an alteration of the recreational experience for residents and visitors to the Project Area. Recreation displaced by project facilities is likely to add use on adjacent federal and state lands.

Dispersed Recreation

Dispersed recreational opportunities in the affected counties include hunting, fishing, sightseeing, and camping. Dispersed recreation, with the exception of hunting, is not a primary use of most federal, state, or private lands that are within the coal boundary of the Project Area. There is expected to be little change in existing levels of dispersed recreational activities on federal and state lands in most of the sub-watersheds within the Project Area as a result of CBM development under the Proposed Action. Existing levels of recreation are expected to continue on these lands. Most of the proposed activity would occur in the Upper Powder River, Little Powder, and Upper Belle Fourche sub-watersheds.

Hunting is the principal recreational activity on federal, state, and private lands in the Project Area. The acreage removed from wildlife habitat by project facilities

394

BEST COPY AVAILABLE

under the Proposed Action is not likely to adversely affect hunting and fishing opportunities within the Project Area. Recreational hunting and fishing opportunities, which are controlled by landowners on private lands, may increase locally within the Project Area. The increase may occur as populations of game animals and game fish rise locally during the life of the project, in response to increased availability of surface water and forage. However, increased access and human activity associated with CBM development may adversely affect wildlife populations that support various recreational activities.

Big game populations in big game management units west of Interstate 25 and in other units outside of the coal boundary would not be affected by project activities. Units that would be affected contain portions of one or more sub-watersheds where CBM development is proposed. The largest effects to hunting would occur in the Upper Powder, Upper Belle Fourche, Little Powder, Clear Creek, Antelope, and Crazy Woman Creek sub-watersheds because most CBM development would occur there. These sub-watersheds contain portions of 10 antelope game units (56 percent of total antelope game units in the Project Area), 10 deer game units (45 percent of total deer game units), and two elk game units (22 percent of total elk game units). Table 4–72 summarizes the number of participating hunters, total hunter days, and non-resident hunters for the big game management units that would be affected by the proposed CBM development in the Project Area. A total of 12,866 active hunters or nearly 47 percent of the total estimated 27,491 active hunters in the Project Area could be affected by removal of wildlife habitat and intrusion of project-related noise, dust, and visual effects from the proposed CBM development in addition to positive effects related to increased access and the potential rise in game and fish populations.

Table 4–72 Big Game Hunting in the Powder River Basin Project Area, 2000

Game Unit	Active Hunters	Total Harvest	Hunter Success (percent)	Hunter Days	Non-Resident Hunters	Percent Non-Resident Hunters
Antelope	4,292	3,907	91.0	10,512	3,276	76.3
Deer	8,347	5,158	61.8	27,695	4,449	53.3
Elk	227	152	67.0	715	31	13.7

Source: WGFD 2001

The development of roads and well facilities would result in greater physical access to the Project Area and potentially increase hunting pressures on wildlife. However, a majority of this access would not be available to the public because much of the surface within the Project Area is privately owned.

Several streams and lakes in the Project Area are used for year-round fishing by local recreationists. All affected fishing areas are within sub-watersheds that would be developed with proposed CBM facilities. Effects to fish and their habitats are evaluated in the section on Wildlife.

BEST COPY AVAILABLE

295

The operators have stated they would work with landowners in the Project Area to enhance the use of the good quality, discharged water. This practice may promote the impoundment of discharged water and use for wetlands and fisheries development. Given the potential quality of discharged water associated with the project in some sub-watersheds, it is reasonable to conclude that enhanced vegetation and increased availability of water probably would have some beneficial effects on fish and wildlife and their habitats and may enhance recreational opportunities in the immediate vicinity of any reservoirs created, which would continue until water production ceases. Water handling facilities would be constructed in sub-watersheds with low water quality for produced water to prevent potentially adverse effects on surface water and fish habitat.

Produced water from CBM wells would be discharged by four methods: surface discharge at outfalls, containment in large upland evaporation reservoirs, spread on the land surface at LAD sites, or injected at an injection well. Effects to recreation from the proposed 323 injection wells would be similar to CBM production well facilities. About 27 LAD sites that occupy 1,728 acres would result in large areas of modified vegetation. Development of LAD sites could have an adverse effect on wildlife and, consequently, hunting opportunities in the affected sub-watersheds because the modified vegetation may affect the quality of the wildlife habitats. There are 142 containment reservoirs occupying 19,880 acres proposed for upland areas. There is potential that infiltration and containment reservoirs would become animal traps. Construction requirements for these structures should include gentle slopes, revegetation, and walk-outs or access control to mitigate the impact to wildlife. Containment reservoirs would create opportunities for some wildlife-related recreational opportunities by providing areas for viewing wildlife, hunting waterfowl, or public fishing. The recreational experience also would be affected by the visual impact of the proposed water handling facilities.

Developed Recreation Areas and Recreation Sites

No CBM facilities are proposed for developed recreational areas or recreational sites in the Project Area. Most of the developed recreational areas identified in Chapter 3 are located in the western part of the Project Area outside the boundary of the coal beds. Special management areas that are on federal lands administered by the BLM are discussed in the section evaluating effects to BLM management of federal lands in the Project Area.

BLM Recreation Management

Specific resources values are assigned under NSO mitigation guidelines to certain federal lands administered by the BLM in the Project Area that include developed recreational sites or recreational activities. Lands managed with NSO include Recreation Areas, such as campgrounds, historic trails, and national monuments, and special management areas, such as areas suitable for consideration for wild and scenic rivers designation.

The BLM administers federal lands in the Middle Fork Recreation Area, the Red Wall/Hole-in-the-Wall area, Outlaw Cave Recreation Site (or Cultural Area), Dull Knife Battlefield site, and the Gardner Mountain and North Fork Wilderness Study Areas. There would be no effects to recreational uses of these special management areas because they are located 10 miles or more outside of the boundary of the coal beds in the Middle Fork Powder Watershed. With the exception of the Middle Fork Recreation Area, these areas have NSO leasing stipulations for mineral development. There would be no effects to the landscape within or near these areas.

NSO has been stipulated for mineral development in the Fortification Creek WSA and the Cantonment Reno, located in the Upper Powder River sub-watershed. No NSO has been stipulated, however, for the Weston Hills Recreation Area, located in the Little Powder sub-watershed north of Gillette. However, no project facilities are proposed for locations within the Recreation Area. Indirect effects to recreational uses would occur as landscapes outside of the areas would be modified by the addition of project facilities and would affect the recreational experience of visitors to these areas. CBM wells are proposed for lands adjacent to Fortification Creek WSA and Weston Hill Recreation Area and would be visible to viewers in the areas.

Private and State Lands

Recreation is not a significant use of most private lands in the Project Area. A limited amount of private acreage is accessed for hunting. Most developed recreation on private lands is municipal facilities in Project Area communities. CBM facilities are proposed for private and state lands outside of and adjacent to Gillette. Recreational facilities that are located on these lands include the Cam-Plex and the Cam-Plex Park. The Cam-Plex facilities occupy about 1,000 acres at the east side of Gillette and include a theater, a convention and exhibit hall, two large multi-purpose pavilions, rodeo grounds, RV campgrounds, a horse race track, a 21-acre park, and a picnic area. Development of CBM facilities would not be compatible with public use of these facilities.

Other recreational facilities located near the municipal boundaries and near proposed facilities include the Dalby Memorial Park, the Country Club Golf Course, and the Bell Knob Golf Course. These facilities would experience indirect effects from the project because the recreational experience would be affected by the sight and noise of CBM construction and operation. No other recreational sites on private lands or within municipal boundaries would be affected by project activities.

Developed recreational opportunities on state lands include big game hunting in the Amsden Creek Winter Game Refuge and the Bud Love Wildlife Habitat Management Area. Both areas are managed with NSO leasing stipulations and would not be affected by project activities.

Alternative 2

Alternative 2 differs from Alternative 1 in the distribution of produced water among the methods for handling produced water and the compression of gas. The numbers and distribution of CBM and non-CBM wells are the same as were evaluated for the Proposed Action. The effects to the developed and dispersed recreational uses from the development of CBM wells and the ancillary facilities other than for handling produced water are identical to the Proposed Action.

Under Alternative 2, there would be 76 LAD sites in the Project Area, an increase of 181 percent over the LAD sites proposed for the Proposed Action. The proposed 117 containment reservoirs would be a decrease of 18 percent from the Proposed Action. The large increase in LAD sites over the Proposed Action would result in larger areas of modified vegetation as described for the Proposed Action. Development of additional LAD sites could have an adverse effect on wildlife and, consequently, hunting opportunities in the affected sub-watersheds because the modified vegetation would affect the quality of the wildlife habitat. The smaller number of containment reservoirs would reduce the opportunities for some wildlife-related recreational opportunities when compared with the Proposed Action by providing areas for viewing wildlife, hunting waterfowl, or public fishing. There would be a larger potential for adverse impact to recreational opportunities in the Project Area from Alternative 2.

Alternative 3

Under the No Action alternative, there would be no CBM development on federal leases within the Project Area. Federal leases are located on private as well as federal lands. Development would continue on state and private leases and would include access and pipelines across federal lands to reach proposed state and fee wells. There would be 15,504 CBM wells developed on state and private leases between 2002 and 2011. The No Action alternative includes all of the effects to recreational opportunities and the recreational experience described for the Proposed Action but differs from the Proposed Action in the number of wells to be developed, the acres of land to be disturbed temporarily or removed from existing uses during the life of the project, and the volume of water to be produced from CBM wells. The effects to recreation are expected to be considerably less than were described for the Proposed Action because a small number of facilities would be developed and a small number of acres would be removed from existing uses. Tables 2-29 through 2-32 summarize the facilities proposed for Alternative 3 and the short- and long-term disturbance for each sub-watershed.

Under Alternative 3, there would be 13 LAD sites in the Project Area, a decrease of 52 percent from the LAD sites proposed for the Proposed Action. The proposed 68 containment reservoirs would be a decrease of 52 percent from the Proposed Action. The fewer LAD sites would result in smaller areas of modified vegetation than were described for the Proposed Action. There would be a lesser effect on wildlife than under the Proposed Action. The smaller number of containment reservoirs would reduce the opportunities for some wildlife-related recreational opportunities relative to the opportunities that would result from the Proposed Action by providing areas for viewing wildlife, hunting waterfowl, or public fishing. There would be a lesser potential for adverse effects to recreational opportunities in the Project Area from Alternative 2 than would occur from the Proposed Action.

Cumulative Effects

The cumulative effect of the development of roads and well facilities would be improved vehicular access to the area. However, a majority of this access would not be available to the public because much of the surface is privately owned and there are no recreational facilities.

The cumulative acreage likely to be affected long-term by production facilities under the Proposed Action (approximately 91,650 acres) is not likely to have a cumulative effect on hunting and fishing opportunities. Recreational hunting and fishing opportunities, which are controlled by landowners on private lands, may increase locally within portions of the area, as populations of game animals and game fish rise locally during the life of the project in response to increased availability of surface water and forage. This small cumulative enhancement of recreational opportunities in the immediate vicinity of any reservoirs created would be temporary and would last only as long as water production continues. Although the project is not expected to affect the level of visitation or growth in the counties, recreational visitors may become accustomed to recreational experiences near ponds or flowing water over the life of the project. Visitors would have to accept anticipated reductions in surface water when discharge of water ends.

Cumulative effects from the increased human presence associated with the cumulative energy development in the PRB are likely to cause increased levels of legal and illegal hunting. Conversely, the mines in the area have become refuges for big game animals during hunting seasons because most are closed to hunting.

Secondary effects related to energy development on recreational land uses have and would continue to result from the growth in the human population. The demand for outdoor recreational activities, including hunting and fishing, have increased proportionately. However, at the same time these demands are increasing, wildlife habitat and populations are being restricted by increased surface disturbance.

Demand for hunting licenses may increase to the point that a lower success in drawing specific licenses would occur; hunting and fishing may become less enjoyable as a result of the more limited success and overcrowding; poaching may increase; the increase in people and traffic has and may continue to result in shooting of nongame species and road kills; and increased off-road activities have and would continue to result in disturbance of wildlife during sensitive wintering or reproductive periods. Travel management during hunting season, including seasonal road closures to the public, could disperse hunters throughout the area, reduce hunting pressure in popular areas, and facilitate a more enjoyable experience for hunters.

It is not anticipated that the Proposed Action and proposed CBM development on state and private lands would result in any increase in population because the proposed workforce would consist be hired locally. However, the overall population of Project Area counties may increase as a result of future coal mine development and expansion of existing mines. CBM fields may continue to be developed within the Project Area and may contribute to ongoing population growth. Any future growth may contribute increased visitor use of the developed facilities.

Noise

EPA has established a level of 55 dBA as a guideline for acceptable environmental noise (EPA 1974). To substantiate this noise level as acceptable near a compressor station, the Federal Energy Regulatory Commission (FERC) has established the same 55 dBA level as the criterion for the maximum noise that can be allowed from a new compressor station at sensitive receptors (residences, schools, medical facilities, and recreational areas). This noise level was defined by scientific consensus, was developed without concern for economic and technological feasibility, and contained a margin of safety to ensure its protective value of the public health and welfare. Furthermore, this noise level is directed at sensitive receptors where people would be exposed to an average noise level over a specific period. In this context, public health and welfare includes personal comfort and well being and the absence of mental anguish, disturbances, and annoyance as well as the absence of clinical symptoms such as hearing loss or demonstrable physiological injury. Therefore, a 55-dBA noise level should not be misconstrued as a regulatory rule, regulation, or goal. Rather, it should be recognized as a level below which there is no reason to suspect that the public health and welfare of the general population would be at risk from any of the effects of noise identified.

A noise level of 55 dBA can be compared with a common human experience. A noise level of 60 dBA is generated during normal conversation between two people 5 feet apart. Therefore, normal conversion would mask the noise level of 55 dBA from a CBM compressor at a sufficient distance from the compressor station.

No laws or regulations on acceptable noise limits have been established in Wyoming. Therefore, lacking any quantitative noise guidelines, noise levels above 55 dBA near CBM facilities at a residence, school, medical facility, or a special recreation area are considered a noise impact. Since the State of Wyoming has not established laws or regulations on noise, the BLM cannot enforce any noise standards on private or state lands. Mitigation measures to reduce potential noise impacts from compressor stations constructed on BLM land may be employed if significant noise issues are identified.

As described on in Chapter 3 of the EIS, the anticipated noise level in rural areas is approximately 40 dBA during the day and 30 dBA during the night. These noise levels assume that these rural areas are distant from transportation corridors (highways and railroads) and populated areas and that the wind speed is very low. However, the wind speed within the PRB project area is generally high. A review of the climatology from the Casper Airport shows that the wind speed exceeds 8 miles per hour (mph) 80 percent of the time between the hours of 7:00 a.m. to 10:00 p.m., and 67 percent of time from 10:00 p.m. to 7:00 a.m. Noise is not usually measured when the wind exceeds 8 mph because the noise produced by the wind is generally the dominant source. Therefore, the estimated existing noise levels are conservative and are most likely 5 to 10 dBA higher during normal windy conditions in Wyoming.

Construction Noise Impacts

Noise impacts during the construction phase would be temporary at any location and would result from vehicles and the operation of construction equipment. Based on an average noise level of 85 dBA measured at 50 feet from a typical CBM construction site, the expected noise levels at would be 85 dBA at 50 feet, 65 dBA at 100 feet, 59 dBA at 500 feet, 55 dBA at 1,500 feet, and 53 dBA at 2,000 feet from the equipment.

Levels of construction noise would fall below 55 dBA at approximately 1,500 feet from construction. Any residences within 1,500 feet of construction would experience temporary noise levels above 55 dBA during daylight hours. Nighttime noise levels would remain at existing levels because construction would not occur at night. Noise from each construction site would be relatively short term, and the individual sites would be sufficiently widespread so that elevated noise levels from each site would not overlap in time or space with other sites.

Noise during the drilling phase would also be elevated above pre-existing levels. Typically, the noise from a drilling rig is 74 dBA at 200 feet from the rig (USGS 1981). Noise emanating from drilling rigs would decrease to 60 dBA at 1,000 feet, to 57 dBA at 1,500 feet, and to 54 dBA at 2,000 feet. Any residences within 1,500 feet of a drilling rig would experience noise above 55 dBA for the 1 to 4 days anticipated to drill the natural gas wells.

Operational Noise Impacts

The highest operational noise would occur around compressor stations. Under all alternatives, two types of compressor engines would be installed. Small booster compressor engines rated at 350 horsepower would be operated to gather natural gas from wells to the larger compressor stations. A maximum of six booster compressor engines could be operated at any location. At the larger compressor stations, large reciprocating engines rated at 1,650 horsepower would be installed to facilitate transmission of natural gas to high-pressure transmission pipelines. Typically, three or six of the larger engines would be installed at any location.

Noise has been measured at typical compressor units (USGS 1981). A noise level of 77 dBA from one large compressor engine can be expected at 50 feet from a compressor building since all compressors would be installed in enclosed buildings because of the harsh Wyoming winter weather. Noise from the smaller booster compressor engines would be slightly lower or approximately 73 dBA at 50 feet.

The effect of multiple noise sources is not arithmetically additive, but rather is a logarithmic addition. The total effect of multiple collocated noise sources is characterized by the following relationship (Harris 1991):

$$L = 10 * \mathrm{LOG}\,(10^{L1/10} + 10^{L2/10} + \_\_\_\_ + 10^{Ln/10})$$

where: L1, L2, ..., Ln are the source sound levels of individual collocated sources.

L is the overall noise level.

LOG is the common logarithm base 10.

Therefore, the preceding equation is used to calculate the overall noise of six large compressor engines operating simultaneously with a source noise of 77 dBA from each engine. The resultant overall source noise would be 84.8 dBA at 50 feet from the enclosure building. The overall noise from a compressor station with three engines would be 81.8 dBA at 50 feet. For the smaller booster engines, the overall noise would be 80.8 dBA at 50 feet for six engines, and 77.8 dBA at 50 feet for three engines.

To calculate the noise impact at a distance from the compressor station, the noise levels were mathematically propagated using the Inverse Square Law of Noise Propagation (Harris 1991). Briefly, this formulation states that noise decreases by approximately 6 dBA with every doubling of the distance from the source. This methodology is an accurate assessment of noise propagation and is represented as:

$$L_2 = L_1 - 20 \log (R_2/R_1)$$

where:

L_2 = noise level at a selected distance R_2 from the source

L_1 = noise level measured at a distance R_1 from the source.

The preceding equation was applied for the source noise for configurations of six engines at a compressor station for both types of compressors. Table 4–73 shows the noise level of the largest proposed PRB compressor station at selected distances from the compressor station. The table also compares the compressor noise to the realistic existing rural noise levels, considering the effects of the Wyoming wind.

The absolute noise level from the largest reciprocating compressor station would be below 55 dBA; there is no reason to suspect that the public health and welfare of the general population would be at risk from any of the identified effects of noise at that level beyond 1,600 feet from the largest proposed PRB compressor station. EPA reported (EPA 1974) that changes in hearing levels of less than 5 dB are generally not considered noticeable or significant. As long as these largest booster compressor stations would be constructed at least 1,600 feet from existing residences, no significant noise impacts would occur. However, noise from these booster compressor engines would be noticed — in other words, would be audible — at distances within 2,800 feet of the compressor station during the daytime and at 9,000 feet from the compressor station during the nighttime hours.

Noise impacts from the largest booster compressor stations (six booster compressor engines) are shown on Table 4–74. Generally, noise from booster compressor engines would be about 4.0 dBA lower than for the larger compressor engines.

The absolute noise level from the largest booster compressor station would be below 55 dBA; there is no reason to suspect that the public health and welfare of the general population would be at risk from any at this level of the identified

302

effects of noise beyond 1,000 feet from the largest proposed PRB booster compressor station. As long as these largest booster compressor stations would be constructed at least 1,000 feet from existing residences, no significant noise impacts would occur. However, noise from these booster compressor engines would be noticed — in other words, would be audible — at distances within 1,800 from the compressor station during the daytime and 6,500 feet from the compressor station during the nighttime hours.

Table 4–73 Predicted Noise Levels from the Largest Proposed PRB Compressor Station (Six 1,650 Horsepower Compressor Engines)

Distance (feet)	Noise from 6 large Engines at distance (dBA)	Noise above Day Rural Background (45 dBA)	Noise above Night Rural Background (35 dBA)
200	72.8	27.8	37.8
400	66.7	21.7	31.7
600	63.2	18.2	28.2
800	60.7	15.7	25.7
1,000	58.8	13.8	23.8
1,200	57.2	12.2	22.2
1,400	55.9	10.9	20.9
1,500	55.3	10.3	20.3
1,600	54.7	9.7	19.7
1,800	53.7	8.7	18.7
2,000	52.8	7.8	17.8
2,200	51.9	6.9	16.9
2,400	51.2	6.2	16.2
2,600	50.5	5.5	15.5
2,800	49.8	4.8	14.8
3,000	49.2	4.2	14.2
3,500	47.9	2.9	12.9
4,000	46.7	1.7	11.7
4,500	45.7	0.7	10.7
5,000	44.8	less	9.8
5,500	44.0	less	9.0
6,000	43.2	less	8.2
6,500	42.5	less	7.5
7,000	41.9	less	6.9
7,500	41.3	less	6.3
8,000	40.7	less	5.7
8,500	40.2	less	5.2
9,000	39.7	less	4.7
9,500	39.2	less	4.2
10,000	38.8	less	3.8

If temporary generators would be used in the PRB, the data supplied by Capstone Turbine Corporation indicate that the source noise from these units would be approximately 65 dBA at 33 feet from the generator. The noise at various distances from the units, shown on Table 4–75, would be below the significance level of 55 dBA beyond 100 feet from these units.

Table 4–74 Predicted Noise Levels from the Largest Proposed PRB Booster Compressor Station (Six 350 Horsepower Booster Compressor Engines)

Distance (feet)	Noise from 6 large Engines at distance (dBA)	Noise above Day Rural Background (45 dBA)	Noise above Night Rural Background (35 dBA)
200	68.8	23.8	33.8
400	62.7	17.7	27.7
600	59.2	14.2	24.2
800	56.7	11.7	21.7
1,000	54.8	9.8	19.8
1,200	53.2	8.2	18.2
1,400	51.9	6.9	16.9
1,500	51.3	6.3	16.3
1,600	50.7	5.7	15.7
1,800	49.7	4.7	14.7
2,000	48.8	3.8	13.8
2,200	47.9	2.9	12.9
2,400	47.2	2.2	12.2
2,600	46.5	1.5	11.5
2,800	45.8	0.8	10.8
3,000	45.2	0.2	10.2
3,500	44.9	less	9.9
4,000	43.7	less	8.7
4,500	42.7	less	7.7
5,000	41.8	less	6.8
5,500	41.0	less	6.0
6,000	40.2	less	5.2
6,500	39.5	less	4.5
7,000	38.9	less	3.9
7,500	38.3	less	3.3
8,000	37.7	less	2.7
8,500	37.2	less	2.2
9,000	36.7	less	1.7
9,500	36.2	less	1.2
10,000	35.8	less	0.8

304

Table 4-75 Predicted Noise Levels from PRB Temporary Generators

Distance (feet)	Noise (dBA)
33	65
100	55
200	49
400	43
800	37

Attenuation of noise by [illegible] is a complex process controlled by the location of the barrier between the noise source and the receptor, the height of the berm, and the resultant difference between the length of the direct sound path (no obstruction) from the source to the receptor and the sound path over the barrier (FHWA 1978).

A noise barrier can achieve at least a 5 dBA noise level reduction when it is tall enough to just break the line of sight between the noise source and the receptor. An approximate 1.5 dBA reduction can generally be achieved with each 3.5 feet of height after it breaks the line of sight. The barrier should be placed on the property line facing the receptor and then extend along the adjacent boundary back toward the noise source to avoid undesirable effects of sound bending around the end of the barrier. If the barrier is not located along the facility boundary to avoid the phenomenon of sound bending around the edge of the barrier, in general the barrier should extend four times as far in each direction as the distance from the receiver to the barrier. Therefore, the barrier should extend 1,200 feet in each direction for a total barrier length of 2,400 feet to properly mitigate the noise from a CBM source to a receptor 300 feet away. A barrier along the CBM property boundary would therefore be approximately 400 feet long. Therefore, a barrier on the property boundary would be much more cost effective and just as functional as a distant barrier to mitigate noise.

In the case of a wall or earthen berm constructed on the property line toward the direction of an existing residence 2,000 feet from a proposed compressor station with six engines, the unmitigated noise would be approximately 54 dBA, a barely acceptable environmental noise level. A barrier that would just break the line of sight between the compressor station and the residence would result in a noise level of 49 dBA at the residence. A barrier that extends 6 feet above the line of sight would result in a noise level of 46 dBA.

Vegetation is believed by many people to be an effective noise barrier. However, studies (Bell 1982) have indicated that a dense stand of trees with a depth of more than 300 feet would be needed to effectively mitigate noise. Conversely, these studies have indicated that a dense stand of trees with a depth of 50 feet would afford no noise mitigation. Therefore, planting vegetation between a CBM noise source and a receptor is not recommended as effective mitigation because of the cost and the time required to grow dense stands of trees.

Finally, compressor stations would have to be constructed further from grouse leks to ensure noise from the stations would be less than 49 dBA.

305

Socioeconomics

Alternative 1

Effects to the socioeconomic structure of Campbell, Converse, Johnson, and Sheridan Counties, including population, housing, and employment, that would result from drilling and constructing ancillary facilities, such as roads and pipelines, are expected to occur over a 10-year period under the Proposed Action. The socioeconomic effects resulting from CBM production are expected to occur over the proposed life to the project, about 20 years. The number of CBM wells is provided in Table 4–76 and the number of non-CBM wells are provided in Table 4–77. Figure 4–48 illustrates the locations of CBM and non-CBM wells by mineral jurisdiction.

Table 4–76 CBM Wells Proposed by Mineral Ownership

County	Number of Wells Drilled on Federal	Number of Wells Drilled on State	Number of Wells Drilled on Fee	Total
Campbell	13,443	963	6,894	21,300
Converse	114	20	42	176
Johnson	7,743	720	2,317	10,780
Sheridan	2,563	841	3,707	7,111
Total	23,863	2,544	12,960	39,367

Table 4–77 Non-CBM Wells Proposed by Mineral Ownership

County	Number of Wells Drilled on Federal	Number of Wells Drilled on State	Number of Wells Drilled on Fee	Total
Campbell	1,578	177	922	2,677
Converse	126	9	65	200
Johnson	175	17	61	253
Sheridan	19	7	44	70
Total	1,898	210	1,092	3,200

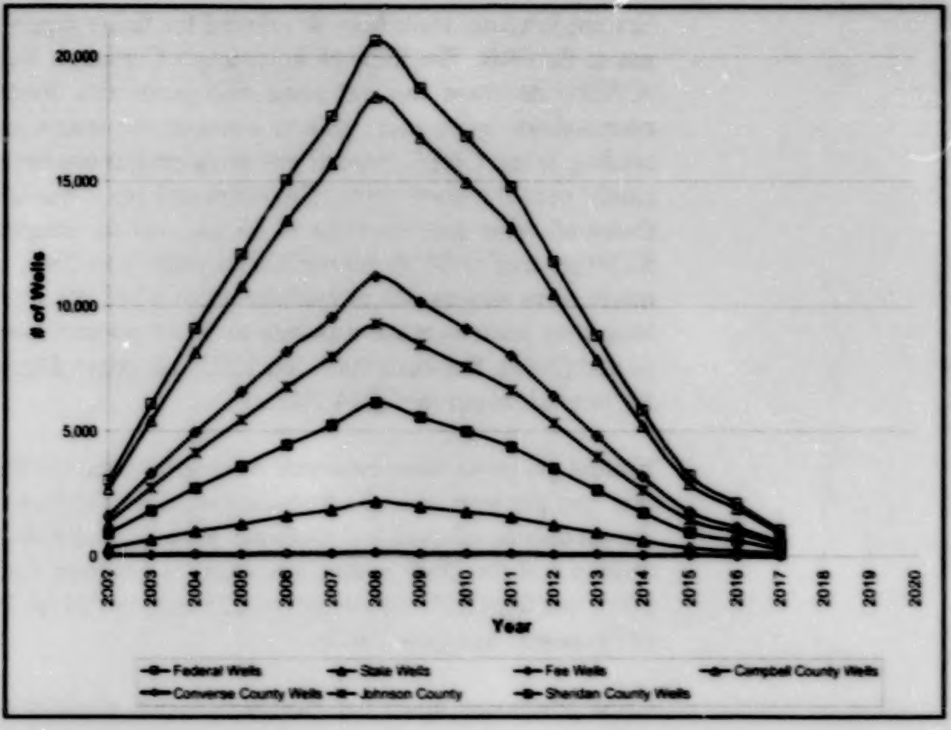


Figure 4–48 Alternative 1 — Wells by Mineral Jurisdiction

Most of the production is expected to occur in Campbell and Johnson Counties. For this reason, Campbell County and Johnson County are likely to be affected by fiscal and social effects. Sheridan County also would experience extensive effects, and the extent of effects in all three counties would be greater than in Converse County. Most of the new wells (63 percent) and facilities would be constructed in the two sub-watersheds: the Upper Powder River sub-watershed, which is within approximately one-third of Campbell County and two-thirds of Johnson County; and the Upper Belle Fourche sub-watershed, which is within Campbell County. Other sub-watersheds where relatively high numbers of wells and facilities would be located include: the north portion of Clear Creek and Upper Tongue River, which are within Sheridan County; Crazy Woman and the south portion of Clear Creek, which are within Johnson County; and Little Powder, which falls in Campbell County. Most of the employees are likely to primarily reside in Gillette and Wright, but employees also would live in Sheridan, Buffalo, and other smaller communities within the Project Area.

Socioeconomic effects that would result from CBM development are a concern because considerable energy-related development has occurred in and around the affected counties during the past 30 years. Wyoming's economy has been structured around the basic industries of extractive minerals, agriculture, tourism, timber, and manufacturing. Many communities in Wyoming depend on the mineral industry for much of their economic well being. The 1999 assessed valuation on all minerals produced in Campbell, Converse, Johnson, and Sheridan Counties accounted for 36.9 percent of the State of Wyoming's total assessed valuation (WDR 2000). In the same year, assessed valuation on minerals produced in the state accounted for 32 percent of the state's valuation (Powder River CBM Information Council 2001).

Several forecasts have been developed for future supply and demand for natural gas in the PRB. The State of Wyoming's Consensus Revenue Estimating Group (CREG) develops mineral price and production forecasts for major mineral commodities twice each year to estimate the state's anticipated revenues. According to the CREG, natural gas price projections have been increased significantly over the short term. The estimated price was increased from $2.85 per thousand cubic feet (mcf) to $3.50 per mcf for calendar year 2000, and from $2.50 per mcf to $4.50 per mcf for calendar year 2001. Calendar year 2002 estimates were anticipated to increase from $2.25 per mcf to $3.00 per mcf. The long-term price estimate was held at $2.25 per mcf over the rest of the forecast period (2006). Between 2001 and 2002, gas prices dropped at the wellhead from $3.94 to $1.98 per mcf (EIA 2002a).

Natural gas production estimates were anticipated to increase slightly by 50 million mcf per year over the forecast period for the State of Wyoming. Estimates for production of coal bed methane were revised from 135 million mcf to 145 million mcf for 2000 production, from 190 million mcf to 175 million mcf for 2001, and from 250 million mcf to 225 million mcf for 2002 (Wyoming Division of Economic Analysis 2001).

CBM production under the Proposed Action would be generated by the 12,024 wells approved or constructed before 2002 and the 39,697 CBM wells drilled from 2002 through 2011. The revenue generated from the existing wells has already begun and are addressed in the analysis of cumulative effects. The assessed sales value from new CBM and new conventional wells are described below.

This analysis used projections for gas production for 2002 to 2020. These prices range from $1.98 per mcf (2002) to $3.26 per mcf (2020) (EIA 2002a). Assuming each CBM well produces 400 million mcf (DeBruin et al. 2001), each well would generate an estimated $792,000 to $1.3 million (constant 2001 dollars) total sales value. Using the projected gas prices, Alternative 1 is expected to contribute an estimated sales value discounted at 10 percent of nearly $21.8 billion (constant 2001 dollars) over the life of the project to the local, state, regional, and national economies.

Non-CBM (conventional oil and gas) under the Proposed Action would be generated by 3,200 conventional wells drilled by the end of 2011. The analysis assumed the conventional wells produce 80 percent oil and 20 percent natural gas (Crockett 2001). In addition, for this analysis, a price of $21.22 to $23.19 per barrel of equivalent (BOE) over the life of the project was assumed (EIA 2002b). The assumed production rate of conventional wells, which average 137,500 BOE (Crocket 2001), for the 15-year productive life (BLM 2001b) was also used for this analysis. Using these estimates, over its productive life, each conventional well would generate an estimated $2.9 to $3.3 million (constant 2001 dollars) net present sales value. The total net present sales value of conventional wells would be approximately $1.5 billion (assuming a 50 percent success rate), of which $1.2 billion would be from oil production, and $0.3 billion would be from natural gas over the life of the project.

Overall, assuming a 100 percent success rate, CBM well development would contribute net present sales value discounted at 10 percent at nearly $21.8 billion

BEST COPY AVAILABLE

(constant 2001 dollars) over the life of the project to the state, regional, and national economies and assuming 50 percent success rate, non-CBM would contribute net present sales value discounted at 10 percent of nearly $1.5 billion. The total sales value resulting from these success rates would be $32.7 billion in sales value. These values do not account for the sales value from the associated facilities or equipment and supplies associated with the facilities for CBM and non-CBM wells, which would contribute to an even higher sales value and thus increase the tax revenue within the Project Area.

Population

Oil and gas operations play an important direct and indirect role in the local economy through jobs that are created in the community. Additional jobs result in additional personal income and improved and or additional community needs, such as schools, utilities, and transportation systems.

The project is expected to result in significant short-term effects to local populations. Assuming the population directly corresponds to workers associated with the project, the population in the region would peak in 2007 and then gradually decrease. It is assumed that most existing full-time workers would be recruited from communities within the Project Area and that construction employment and contractors would be available in the region (Keanini 2001a). To the extent that additional non-local contractors or permanent employees are needed, they may relocate to the area for a limited period (2 to 5 years) during the major construction phase of the project (Keanini 2001b). Substantial CBM exploration and development are currently ongoing in the counties. Up to 2,660 workers would be required during peak employment, in addition to the existing 2,943 workers in the region. Assuming each worker brings one person to the region, the population would increase by 5,320 in the peak year (2007), which would result in a 7 percent incremental increase in population between 2000 and 2007 from the project. After 2007, the population associated with the project would be expected to gradually decrease. During the short term, this increase in population will be noticeable in some communities and could result in hardships to the local governments, if adequate planning has or does not occur. However, in the long term, the project will not have significant long-term effects to local populations.

Direct and Indirect Employment

Implementation of the Proposed Action would have a substantial effect if it resulted in a negative change in local economic conditions or wages, resulted in a short- or long-term reduction in employment, or created the potential for a boom/bust employment cycle. Development of the project would be completed in approximately 10 years from initiation. The overall production lifetime of the wells is expected to be in the range of 7 years. This estimate includes the 12,024 CBM wells already permitted in the Project Area, in addition to the 39,367 CBM wells and 3,200 non-CBM wells proposed. Both direct project employment (for example, positions with one of the companies or contractors hired for construction, production, and decommissioning) and indirect or secondary employment (jobs that become available in support industries as a result of project activities, such as parts and materials production and equipment refueling) would arise as a result of the project.

Direct Employment

Implementation of the project would create some additional employment opportunities in the Campbell, Converse, Johnson, and Sheridan Counties; however, it is anticipated that most of the jobs would be hired from the local labor force (Keanini 2001a). For the existing employment, the following is assumed: (1) willing workers will be available for employment from the current residents of the region to meet the CBM employment requirements; (2) workers will come from the existing oil and gas industry and already have the necessary education, skills, and training to fill the job positions involving the exploration, development, construction, operation, and reclamation of CBM and non-CBM development; and (3) a limited number of unsuccessful in-migrating job seekers would not have an appreciable impact on the region's infrastructure. However, in addition to this base workforce, who already resides and works in the region, an incremental increase in workers will be necessary between 2003 and 2011. Up to 2,660 additional workers will be required for the project in the peak year (2007). These additional workers will either come from outside the region, or they currently live in the region, and will obtain the necessary education, skills and training to fill the job position for the project.

Currently, most of the existing local labor force lives in Wyoming (Keanini 2001a). Assuming that employees work in the same counties in which they live and assuming future employment would be similar to 2001 fourth quarter employment, it is estimated that up to 85 percent of these employees would live Campbell County, 6 percent would live in Converse, 5 percent would live in Johnson County and 4 percent would live in Sheridan County.

As shown in Table 3-92, it is estimated that CBM workers occupied 2,943 CBM related jobs within the four-county region as of 2001. During the peak employment period (2007) up to 2,660 employees would be required to staff the Proposed Action, which is an employee incremental increase of 90 percent.

The following text identifies employment needs for non-CBM activity and additional facilities required. Non-CBM estimates are based on wells and roads projected; however, it is assumed that adequate workers required for non-CBM compressor, pipeline, and utility lines construction are accounted for in the CBM facility estimation.

An increase in population between 2001 and 2002 likely occurred; however, the increase is not accommodated in this analysis because of the ever-changing demographic situation. As discussed in Chapter 3, the communities within the Project Area have been affected by the existing CBM development, some more than others. These effects will continue and may even be magnified, especially in communities such as Gillette, during years of peak activity. Population related impacts are only forecasts, based on limited oil and gas related information, and are not a certainty.

Direct employment by each development phase is shown in Figure 4-49. Text following Figure 4-49 further explains direct employment for Alternative 1.

In light of the long-term nature of the project, coupled with fluctuation in natural gas economics and the companies involved in the leases, developing exact projections of employment is difficult. Therefore, the following paragraphs provide a reasonable estimate of what employment effects can likely be expected with project implementation.

Construction and Installation

The primary influx of employment opportunities associated with the project is expected to occur in the first 10 years of the project, during the development phase. During this phase, the primary activities would be well drilling and completion and construction of associated ancillary facilities (for example, access roads, pipelines, power lines, and compressor stations). As shown in Tables 2–16 and 2–20, it is anticipated that these activities would require 506 workers during peak construction. After the initial 10-year development period, rigs would drill replacement wells for those depleted plugged and abandoned, or for isolated filed development. Non-CBM development would require 76 workers per year for the life of the construction phase of the project.

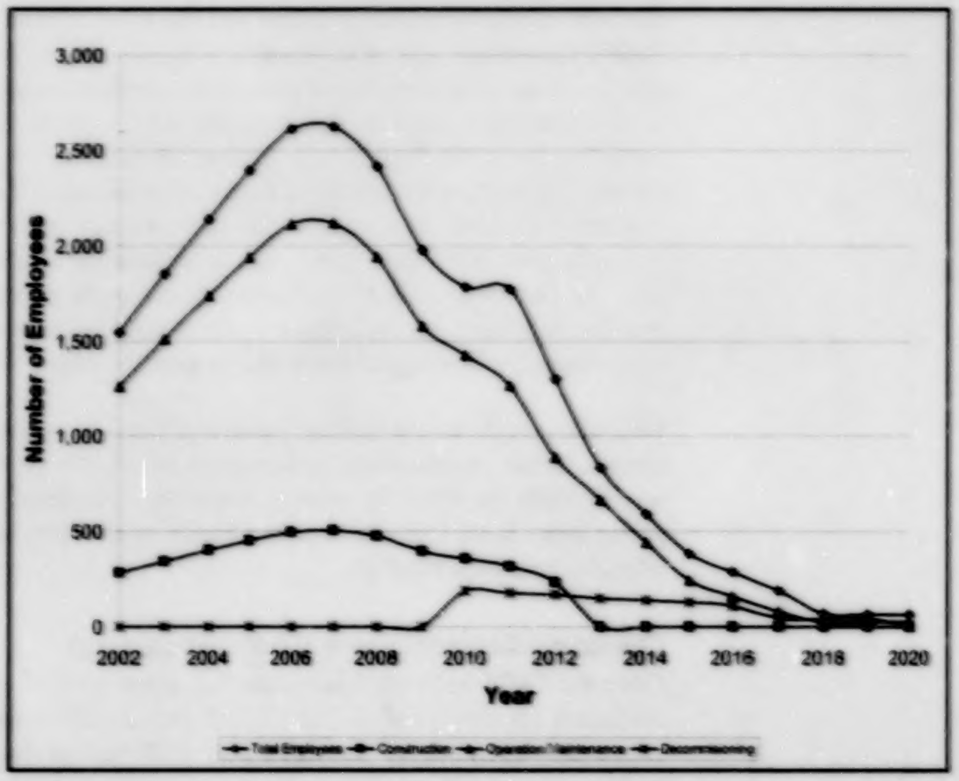


Figure 4–49 Alternative 1 — Direct Employment from CBM Wells

Employment opportunities are expected to be the greatest over the first 10 years (the construction phase) and then constant over the remaining life of the project. Employees and contractors would be hired or reassigned because, for the most part, they already work in the area to construct and maintain roads and well pads, construct utility trenches, and install underground gas pipelines, water pipelines, and utility lines. Local contractor jobs would include gravel and water truck drivers, heavy equipment operators, and pipeline workers, made up primarily of workers currently located within the Project Area.

The proposed use of non-local construction workers for specialized construction (pipeline construction) would include about the same number of workers that have been used in recent years. Depending on the construction time frame, they would result in 46 to 97 additional workers. Because of the extent of the project, these temporary workers could be employed in the region for 5 to 10 years. It would be likely that most of these employees would rent or possibly buy homes within in the Project Area. In the event that these workers have families, they would likely relocate their families based on the extent of time that they would be working in the region. Assuming a mixture of single employees and employees with families, it is estimated that on average, each new specialized construction employee would bring one additional person to the region. Even if all of these specialized jobs (97 at peak construction in 2007) were filled by new an in migrating population, the total construction related population (approximately 194 persons) would be small compared with the total regional populations (79,385 in 2000). Given that any new population would spread over both time and geographic area, no impact on demographics would be anticipated non-local specialized construction workers from this alternative. In the event that these workers would reside in the Project Area for about 6 months each year (May through November) during the construction season, it is assumed that the majority of these workers would reside in motels while they are working in the area and would not bring families with them. Many of these contractors would leave the Project Area once the construction and development phase of the project is finished. Given the number of short-term specialized workers and family members, the local motels and temporary housing facilities will support the influx of temporary residents.

Necessary skills would include: pump and pipeline maintenance, compressor and electric motor maintenance, and production monitoring. Many of these positions would likely be filled by workers currently underemployed in service or trade sector jobs. Some jobs that require a higher or different level of expertise may be filled by non-local workers.

Operation /Maintenance and Decommissioning

Once the CBM wells have been installed, some level of sustained permanent employment (as described in Tables 2–16 and 2–20) would be related to maintenance and operation of the fields over a 20-year period. Additionally, gradual reclamation of the inactive wells, and associated access roads would be an on going effort in the later years of the project. Fewer workers would be required to perform these functions. Approximately 2,116 CBM workers and approximately 42 non-CBM workers would be required for the operation and maintenance phase during peak years. The majority of these workers would be pumpers. Implementation of remote monitoring is anticipated to decrease the number of workers traditionally required for operation and maintenance.

The final stage of the project life cycle involves the reclamation and abandonment of facilities, which may also create 189 jobs for CBM and 23 jobs for non-CBM wells during the peak reclamation year, when the various facilities would be dismantled and removed or abandoned in place and surface areas are reclaimed.

As a result of the Proposed Action, at a minimum it is assumed that 2,660 employees would be required for the peak of activities for the project. It is assumed, that because of the revolving nature of CBM employment, almost 3,000 of these employees already live in the area and would be available for work (Keanini 2001a).

Indirect Employment

In addition to the CBM and non-CBM related jobs to the local economy, during the life of the project purchases and expenditures made by project employees within and outside of the affected counties, which would in turn extend the length of time of secondary jobs for the life of the project. Assuming a multiplier of 2.4 (BLM 1999c), 7,063 secondary jobs have been created as a result of the existing CBM development. Of these jobs, approximately 50 percent or 3,514 jobs have been created in the affected counties (BLM 2000). These jobs currently contribute personal income to the local economy and will continue to do so as a result of the Proposed Action. Assuming parallel secondary employment between the existing and project-related secondary jobs, during peak activity, up to 6,384 additional secondary jobs would be created, of which 3,192 would be created locally. However, because most of these jobs have been filled by employees living in the area, it is anticipated that few secondary jobs would be created, but may sustain for a longer period than was previously anticipated. Additional secondary employment will likely be filled by residents of the region who are currently unemployed or by workers who move to the region. Since the vast majority of service and retail trade activity occurs in the Gillette, Wright, Buffalo, and Sheridan communities, it is assumed that most of these jobs would be created in these or nearby communities in Project Area. The other 50 percent or 3,192 additional non-local secondary jobs will also be sustained as a result of the Proposed Action. Non-local secondary employment will likely result in spending within the Project Area and outside the region as a result of travel expenses. Non-local workers with specialized skills will likely relocate to the Project Area for the 2 to 5 year construction time frame. These workers will likely spend personal income within the Project Area for the majority of the construction time frame.

Wages

The project also would contribute to the local economy by generating earnings that would be spent on items such as housing, food, goods, and services. In addition, economic benefits would occur as a result of the Companies spending on purchases of equipment and supplies from local area vendors.

The wages and salaries paid to long-term project employees would contribute an estimated net present value of annual personal income to the local economy discounted at 10 percent of $570 million (in constant, 2001 dollars), using an average annual income of $40,000 (Powder River CBM Information Council 2001). The average annual income would primarily be contributed to the affected counties. The annual net salaries for Alternative 1 are shown in Figure 4-50. The second small peak is caused by an increase in reclamation.

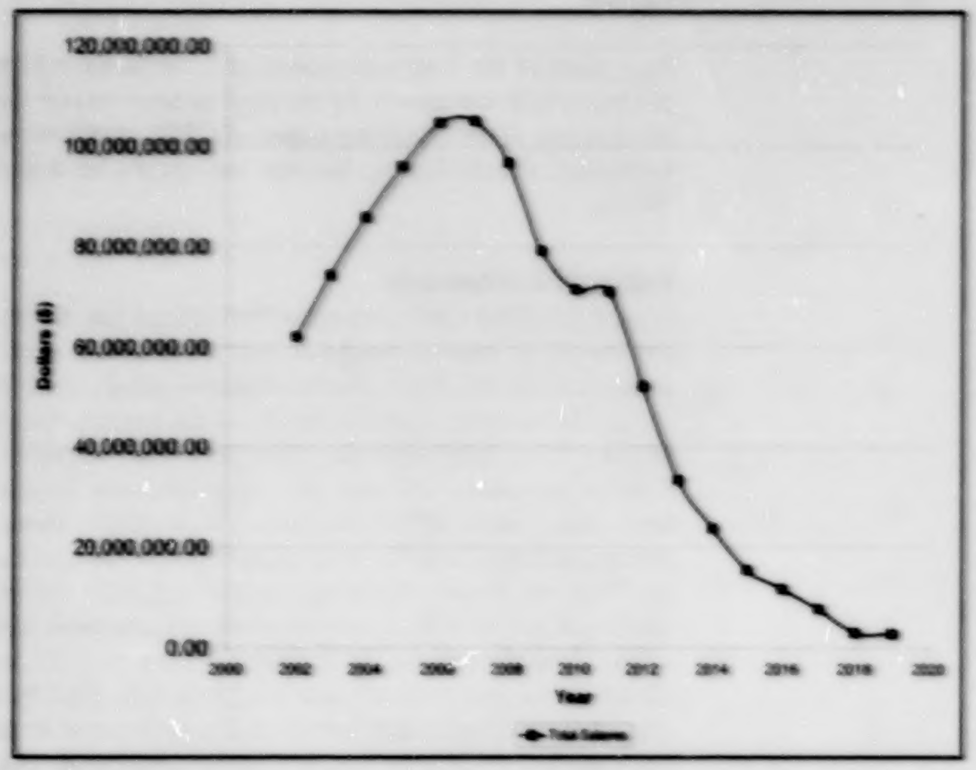


Figure 4–50 Alternative 1 — Total Annual Salaries from CBM Wells

As the life expectancy of the project nears completion, additional costs and expenditures would occur as wells are plugged and decommissioned. Projections of these costs are unavailable at this time. Both expansion of existing businesses and creation of new business can be anticipated as a result of the increase in longevity of existing jobs. However, after the development phase of the project is completed, a reduction in employment in the service and trade sectors can be anticipated. Some additional earning from indirect employment also can be expected, and these earnings would be spent in, and contribute to, the local economy. Once the development phase of the project is completed, indirect earnings from secondary employment would eventually be reduced.

Local Economy and Potential for Boom/Bust Cycle

Implementation of the project would create both primary and secondary employment opportunities, contribute to the local economy, and provide a substantial source of revenues for local agencies through the collection of royalty taxes. If current estimates and plans are realized by each of the Companies involved in the project, it is assumed employment opportunities would occur primarily in the first 10 years of the project. Revenues may extend for as long as 20 to 30 years when project activities and gas production would slow or cease and so would the associated economic benefits. Some concern was expressed during scoping related to the potential of project activities to create a boom/bust economic cycle similar to the experience in the area in the early 1980s.

The potential for the project to result in a substantial economic boom/bust cycle is moderate. By adding wells to an area that may already be subject to slight boom/bust cycle, the project would likely extend the locally strong economy longer than previously anticipated. While this project would increase the importance of these sectors in the local economy, when compared with the overall economy these activities represent a relatively small share of the economy. Project activities are expected to begin and end in a gradual fashion, and a major layoff or royalty reduction is not anticipated. Historically, the economies of counties with in the Project Area have been subject to the fluctuations associated with resource extraction and are probably less sensitive to this phenomenon than are other areas. In addition, there are a number of other ongoing economic activities and concerted efforts by local authorities to diversify the local economy. These factors all lead to the conclusion that while the conclusion of project activities would create a gap in employment and the economy, it is not expected that this gap would equate to the overall collapse of the region or a significant localized depression cycle. Although there is a risk for the oil and gas industry and potential for some risk to the local economies, there would be minimal risk to the overall economy of the Project Area.

Housing

To the extent that employment created by the project results in a concentrated demand or shortage for housing, either short- or long-term, the effect of the Proposed Action would be considered significant. Effects would be measured on both a local and regional level. If transient housing, for example, man camps or motel rooms, would be required for short-term accommodations for construction or other laberers that are currently not available, the effect is deemed significant.

Minor changes in employment or population are anticipated as a direct result of implementation of the Proposed Action. The increase in population would be gradual and small (7 percent at peak activity) relative to the total population. Because most employees are expected to be hired locally, the demand for additional temporary or permanent housing within the near the Project Area likely may be met with the existing housing supply, depending on the vacancy rates during the period of operations. The majority of available and proposed housing units in the Project Area are located in the communities of Gillette, Wright, Sheridan, and Buffalo, and it is anticipated that the majority of employees would live in Campbell County.

However, during years of peak activities (2003 to 2011), the local communities have the potential to lack adequate housing. Several housing developments are being considered in the Project Area that could increase the supply of available housing. Assuming these housing developments are approved in a timely manner, the number of new residents associated with the Proposed Action would not adversely affect the local housing market. However, if these housing developments are not constructed by 2004, the workers for the project will exceed the supply of housing in portions of the Project Area. If these housing developments are not constructed at all, the housing and rental vacancy rates would continue to narrow, and the Proposed Project would aggravate the housing situation in some portions of the Project Area. Based on the existing housing and vacancy rates in Sheridan, Johnson and Campbell Counties, these counties would be affected the most as a result of additional employees needing housing.

Community Facilities and Services

Roads, Water and Wastewater Systems, and Solid Waste Disposal

Access to portions of the Project Area from state and federal highways would require the use of certain county roads. Project activities could result in increased traffic and use of roads, including additional wear and tear from heavy vehicles. The increased use of county roads may increase maintenance costs to county special districts. Both paved and non-paved roads may be affected. The project's effects on roads are described in the Transportation section of Chapter 4 starting on page 4–298.

Water would be required for construction and operation of the project. Total water requirements would equal 6,963 acre-feet/year. The Companies would purchase water locally from a variety of sources, resulting in minor shifts in water consumption from existing uses to this project.

Because only a small and gradual population increase and subsequent housing demand is expected with project implementation, a significant effect on provision of domestic water service (in terms of supply and conveyance systems) is not expected. In addition, neither the project itself nor subsequent development resulting from project employment (if any) is expected to have any effect on local wastewater facilities. Certain wastes would be disposed of on site or recycled and other waste products would be disposed of at the local landfill. It is not anticipated that addition of this waste stream would substantially affect the local landfills or their capacities.

Public Schools, Law Enforcement, Fire Protection, and Medical Facilities

Public schools in the region are not anticipated to experience significant increases in student enrollment as a result of the project. Based on the limited population increases expected and the long-term time frame associated with the project, public schools are not anticipated to experience potential effects of substantial growth resulting from the project. If current plans change, resulting in a significant number of project workers who are recruited from outside the local area who bring school-aged children with them, existing overcrowded conditions may be exacerbated.

Law enforcement, fire protection, and medical services are not expected to experience substantial effects as a result of project implementation because the long-term growth in population is expected to be consistent with typical growth rates. However, additional law enforcement, fire protection, and medical services may be required during years of peak activity.

Public Finance

The project would be considered to have a significant effect on public finance if the fiscal conditions of local governments were affected in such a way that revenues would not adequately provide public facilities and services at established levels.

Implementation of the Proposed Action would result in some level of both costs and benefits for the counties in the Project Area. Regarding financial costs, the primary project-related impact is related to the use of county roads. Revenues used by these counties are generated through federal mineral lease royalties, state payments in lieu of taxes, and interest earned on unanticipated funds. Additional project-related costs to the counties may arise from administrative services. Examples of these costs include mapping, naming, and signing of new roads developed in the Project Area for emergency access, as well as other staff and administrative costs.

The analysis is based on the net present value of discounted cash flow for revenue, royalties, state, and local taxes. For the purpose of this analysis, the discount rate assumed is 10 percent. This analysis does not reflect deductions from revenues such as taxes, royalties, transportation costs, nor does it assess the revenue generated from other Project related infrastructure. These revenue sources discussed are some of the major revenue streams but are not all encompassing of all revenue streams to the governments as a result of the project. A summary of the revenues, royalties, state, and local taxes generated from CBM and non-CBM wells in Alternative 1 are shown in Figure 4–51 and Figure 4–52. The text following the graphs serves as an explanation for the public finance revenues.

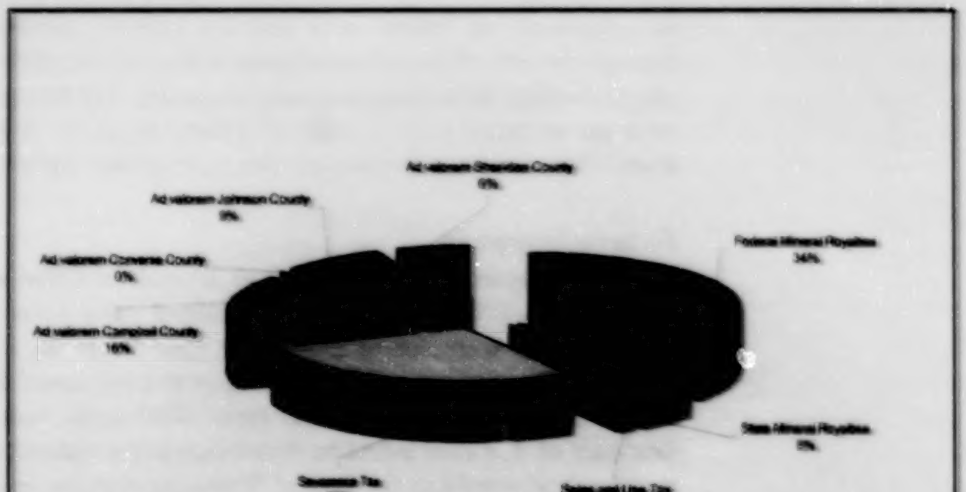


Figure 4–51 **Alternative 1 — Net Present Value of Taxes and Royalties from CBM Wells**

317

Mineral Royalties

The Mineral Management Service, U.S. Department of the Interior, collects mineral lease royalties, for gas produced by wells completed on federal lands. Federal royalties would be paid for each well producing from federally owned oil and gas mineral estate. After administrative costs are deducted, half of the royalties would be retained by the federal government and used for the General Fund and various other funds. The remaining half would be distributed to the State of Wyoming and used for schools, roads, and other public works. For this analysis, royalties are estimated as percentage of the total project yield for each well multiplied by the market price for the product.

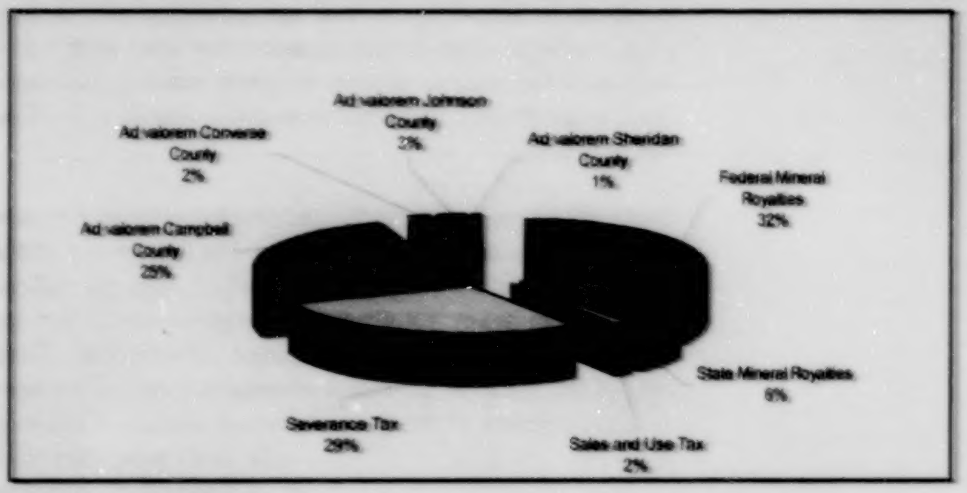


Figure 4–52 Alternative 1 — Net Present Value of Taxes and Royalties from Non-CBM Wells

It is estimated that about 39,367 CBM wells and 3,200 conventional wells would be completed on federal, state and fee (private) minerals in the Project Area through the end of the estimated project life. Substantial revenues would be generated through these mineral royalty payments. For this analysis, all federal revenues are assumed to be a result of mineral royalties. It is assumed that revenue from leases and lease bonuses are not a part of this analysis.

Federal Royalties

For this analysis, federal royalties as a result of CBM activity have been estimated using 12.5 percent of the estimated sales value for each well. Of the 39,367 CBM wells, up to 23,860 are expected to be CBM wells with federal minerals. The project is expected to generate estimated federal royalties of $1.6 billion (in constant 2001 dollars) from CBM wells over the life of the project. One-half of this total would be distributed to the federal government, and the remaining half would go the State of Wyoming based on equivalent royalty rate.

Of the 3,200 conventional oil and gas wells, up to 1,888 are expected to be federal wells. Assuming 50 percent success, the project is expected to generate federal royalties of an estimated $105 million (in constant 2001 dollars) from conventional wells over the life of the project. Half of this total would be distributed to the federal government and the remaining half would go the State of Wyoming.

BEST COPY AVAILABLE

3/8

Overall, the Proposed Action would result in approximately $1.7 billion in federal royalties.

State Royalties

State royalties would be paid for each well producing from state owned oil and gas mineral estate. State surface does not always correlate with state minerals; however, for this analysis, data on state minerals were calculated using state surface with non-federal minerals based on the lack of available data on state mineral ownership for the entire Project Area. Using this assumption, there are 2,547 CBM wells on state minerals. For this analysis, State of Wyoming royalties have been estimated using 16.67 percent of the estimated sales volume for each well. The project is expected to generate $234 million (in constant 2001 dollars) in state royalties over the life of the project. State royalties are deposited in the permanent fund and are used for schools and public institutions.

Using the assumptions above for state minerals, there are 214 conventional wells on state minerals. For this analysis, State of Wyoming royalties have been estimated using 16.67 percent of the estimated sales volume for each well. Assuming a 50 percent success rate, the project is expected to generate $17.7 million (in constant 2001 dollars) in state royalties from non-CBM over the life of the project. State royalties are deposited in the permanent fund and used for schools and public institutions.

Overall, the Proposed Action would result in approximately $252 million in state royalties.

Fee Royalties as a result of CBM and Conventional Well Development

Fee royalties would be paid in royalty owners of each well producing from the privately owned mineral estate. The amounts paid as fee royalties are not available to BLM. State and county governments do not receive royalties generated from the private mineral lands, but collect severance and ad valorem taxes, and sales and uses taxes.

Sales and Use Tax Revenues

The Proposed Action would contribute to revenues of the State of Wyoming and its counties through sales and use taxes from the purchase and use of tangible goods. The State of Wyoming collects a 4 percent sales and use tax for each well, and the counties each collect 1 percent per well, for a total and use tax of 5 percent (BLM 1999c). State taxes are retained by the state and are partially disturbed to county and municipal governments. County sales and use taxes are distrusted primarily to the counties that impose the tax.

Sales and use taxes for oil and gas operations are applied to the following categories of tangible goods and services that are purchased or used during the CBM development: (1) coring or sampling; (2) well logging; (3) formation testing; (4) plugging and abandonment; (5) production casing; and (6) well completion. Generally, those services directly related to drilling are not taxable. Well maintenance and repair services are taxable. Purchases of separate lines, tanks, and other units used in the collecting, processing, or transporting oil and gas are taxable.

The taxable value per CBM well is estimated to be $36,000. This figure was calculated by applying an estimated factor of 60 percent (taxable goods and services) to a total drilling and completion CBM well cost of $60,000 (Western 2001). There would be 39,367 CBM wells, resulting in $71.8 million in taxable drilling costs. For this analysis, non-CBM wells would be assumed to have similar sales and tax revenue per well, which would contribute an addition $5.6 million in taxable drilling costs. All of these expenditures are subject to sales revenue and tax, totaling $77.4 million paid to the state and the counties over the period that taxable goods and services are purchased (life of the project).

Additional sales tax revenues also would be generated from the cost of the other water handling facilities. The sales tax over the life of the project from water handling is shown in Table 4–78. Because sales taxes are based on tangible goods and the design of the water handling methods remain on a conceptual level, tangible goods were based on estimates and assumptions. These costs are incomplete and are presented only to be used as a comparative analysis. The total sales tax revenue generated from water handling of this alternative is estimated to be $47 million for the life of the project. Capital costs of containment reservoirs vary depending on design and the materials utilized to construct the structures. Clay liners would be most economical and would be used when possible. If clay is not within a 20-mile round trip of the proposed location, a plastic geo-liner would prove more economical.

Overall, CBM and non-CBM activity in the Proposed Action would result in approximately $124 million in sales tax returned to the state and counties, over the life of the project.

Table 4–78 Water Handling Sale Tax Revenue

Type of water handing facility	Sales tax generated from water handling facility (millions)[2]
Surface discharge — Untreated	$23.2
Surface discharge — Active Treatment	0.0
Surface discharge — Passive Treatment	1.3
Infiltration	$15.2
Containment[1]	$2.8
LAD	$0.8
Injection	$3.8
Total	$47.2

Note:

1. Operation and maintenance unknown and therefore not included.

Source: CBM Operators Information Survey Results Report, 2001; Williams, 2001; and Kolin 2002.

2. Not calculated using net present value.

BEST COPY AVAILABLE

320

For CBM wells, severance taxes on fee wells are calculated at a 6 percent rate for the State of Wyoming. The 39,367 wells would generate $1.3 billion in severance tax over the life of the project paid to the State of Wyoming. Assuming a 50 percent success rate, the 3,200 non-CBM wells will generate $91 million in severance tax over the life of the project paid to the State of Wyoming

Over all, CBM and non-CBM wells in the Proposed Action would result in approximately $1.4 billion in severance tax distributed to the State of Wyoming.

Local Ad Valorem Tax Revenue

Additional project revenues would be generated throughout the collection of an ad valorem or property tax levied on improvements constructed by the Companies. Since this tax assessment is based on value added to property, revenues would increase based upon the number and location of wells. No estimate of the assessment of improvements associated with well development were available, however, assessed value would be determined as a percentage of the actual cost of the facilities (BLM 1998). Theoretically, revenues would gradually increase over the first 10 years in all four counties, provided a steady revenue stream for a period of years, and then decline as facilities are dismantled and reclaimed. Counties are often in a position to provide the necessary infrastructure and personnel associated with the development prior to receiving revenue from this stream due to a lag time that can last up to 18 months. As a result of the current tax system, it is imperative that these governments carefully work with industry, the state and federal government to economically and socially plan for potential development related effects. Figure 4–53 shows the local ad valorem tax revenue by county jurisdiction. These projections are subject to the number, locations, and life span of facilities and gas production.

County ad valorem tax rates for Campbell, Converse, Johnson, and Sheridan Counties vary slightly. In Campbell and Converse Counties, the tax rate is 6.3 percent and in Johnson and Sheridan Counties the tax rate is 6.8 percent (BLM 2001). As shown in Table 4–79, Campbell County is estimated to receive $821 million (in constant 2001 dollars) in ad valorem taxes from CBM and non-CBM wells, the highest of the four counties in the Project Area. Johnson County is estimated to receive $413 million in ad valorem taxes from CBM and non-CBM wells, the second highest amount of the four counties in the Project Area. Sheridan County is estimated to receive $269 million in ad valorem taxes form CBM and non-CBM wells and Converse County is estimated to receive $12 million in ad valorem taxes form CBM and non-CBM wells.

Over all, CBM and non-CBM wells in the Proposed Action would result in approximately $1.5 billion in ad valorem taxes for the four counties within the Project Area the county governments use to fund vital programs such as public schools, hospitals, libraries, and special districts, including conservation districts (Powder River CBM Information Council 2001).

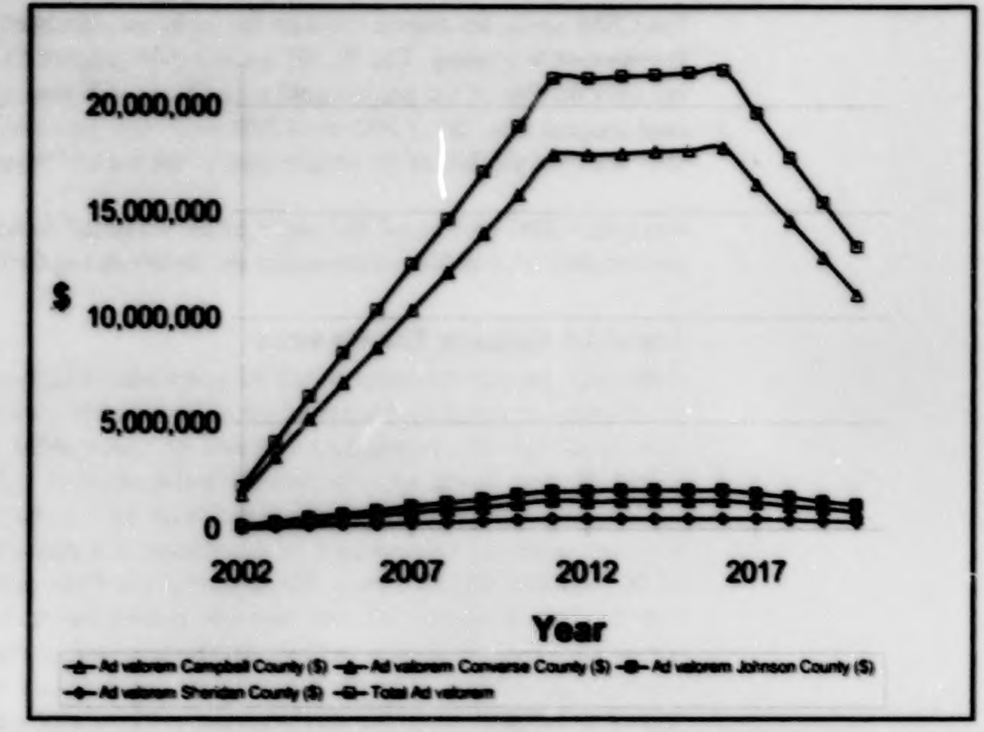


Figure 4–53 Alternative 1 — Ad Valorem Taxes by County

Table 4–79 Ad Valorem Taxes by County

Source and Location	Wells Proposed[1]	Ad Valorem Rate (percent)	Sales Value of the Well (dollars)	Net Ad Valorem (dollars)[2]
CBM			792-1.3 million	
Campbell	21,300	6.3		741 million
Converse	176	6.3		10 million
Johnson	10,780	6.8		405 million
Sheridan	7,111	6.8		267 million
Total				1.4 billion
Non-CBM			2.9 – 3.3 million	
Campbell	1,339	6.3		30 million
Converse	100	6.3		6 million
Johnson	126	6.8		8 million
Sheridan	35	6.8		2.2 million
Total				96 million
Grand Total				1.5 billion

Note:

1. Assumes 50 percent success rate.
2. Net present value of ad valorem tax discounted at 10 percent.

Source: BLM 2001c

Based on these assumptions, it is estimated that revenues from sales and use tax, severance tax, and ad valorem tax generated over the life of the project would be $3.0 billion ($1.5 billion ad valorem, $1.4 billion severance, and $124 million sales tax), which would represent a significant impact to the state and local economies.

Quality of Life

Project-related changes in existing ways of life that cause community discontent sufficient to raise conflict and organized response or opposition would be considered to represent a significant impact on quality of life. The perception of a "quality of life" is a subjective and personal and varies significantly by individual, location, and interests. Quality-of-life issues were raised as part of scoping for this project; however, little information regarding a definition of this issue was provided by respondents. During scoping, one commenter states the quality of life considerations are a conglomerate of every aspect of life, consisting of tangibles and intangibles. Tangibles include factors such as noise, air, visual impacts, while intangibles consist of community values and social concerns.

It is clear that no one would be in favor of a "poor" quality of life, but it is difficult to assess what specific aspects of a long-term project may cause the perception of quality of life to change in a negative manner.

Many of the social concerns and community values toward existing oil and gas development are presented in Chapter 3 and generally can be applied toward concerns voiced during scoping with respect the Proposed Action. As discussed in Chapter 3, many view additional CBM development as a positive impact to the community because of the employment and revenue streams that are generated. Others view the additional development adversely because of the increased dust, traffic, noise, modification to the natural landscape, and the stress that results from disruptions of daily activity as a result of working with industry on surface owner agreements and related activities. The physiological stresses that result from these impacts, both positive and negative, are beyond the scope of this analysis, given the variability in the ways individuals react and cope with stress. It is anticipated that an increased number of CBM and non-CBM wells will magnify and extend the community values and social concerns for a longer amount of time than previously anticipated.

Additionally, many of the factors that would be considered by most to improve a quality of life (for example, employment opportunities, municipal services, and vital economy) may or may not be achievable without some increase in factors seen to mar a quality-of-life perception (for example, traffic increase, visual impairment, use of federal lands for resource extraction, or influx of transient workers). Each of these factors is discussed in the following paragraphs.

Local Economy

Over time, the project would result in effects that would be considered to both aid and deter from a common perception of a desirable quality of life. All of the social and economic topics described in this section would factor into a "quality of life." It has been concluded that increased employment in certain sectors would be realized over the 20-year expected life span of the project. These op-

393

portunities (primarily within the first 5 years of project development) would require skilled as well as unskilled labor. Many of these jobs could be filled by workers with similar skills who are currently residing in the Project Area. Employment opportunities and economic stability are a positive factor in the quality of life.

Visual Effects

Project development would noticeably increase activities on federal lands throughout the Project Area. During the 10-year development phase, it is expected numerous ongoing drilling operations would increase noise and dust and pose local visual impairment. Once wells are completed, well pad and pumping units would occupy the landscape in certain areas. New road and pipeline corridors also would be noticeable. These effects are a necessary part of resource extraction activities in the area. These features may affect the perception of quality of life in terms of a visual impact experienced. Some members of the community are sensitive to development and find these impacts extremely noticeable, while other members of the community may not find these impacts to be very noticeable. Localized visual effects, while unavoidable with project implementation, can be lessened by some extent through mitigation, such as screening and painting.

Traffic Congestion

Implementation of the project would result in an increase in traffic on federal, state, and local roads. Truck and heavy equipment traffic on federal lands, state highways, and county roads would increase. Some additional traffic on local community roads also may occur over time as new employees and project activities create additional trips. The major traffic congestion would occur at locations along Interstate 25, Interstate 90 and State Highway 59 where vehicles and construction equipment would enter and exit the Project Area. Additional traffic related effects that affect quality of life are also presented in the section of Chapter 4 on Transportation.

Climate and Air Quality

Climate and air quality are discussed in detail beginning on page 4–354.

Community Facilities and Services, Community Values

As described in previous sections, the project would generate revenues that are currently not available to Campbell, Converse, Johnson, and Sheridan Counties. These revenues would likely be used for a variety of purposes, including funding for additional community facilities and services. Counties can struggle to provide the necessary infrastructure and personnel because of the lag between when the revenue is generated and when the county receives it. Although there may be a moderate increase in demand on existing services over time as the project proceeds, these effects have not been determined to be significant. Careful planning and budgeting of revenue would allow municipalities to consider such things as school additions, parks, recreational facilities, additional law enforcement officers, and other services and facilities.

324

Based on community values voiced, there is concern of the fragmentation of community and family relationships; the increasing loss of local control and powerlessness, both in terms of decision making at the community and political level, but at the household and private property level; the breakdown of such rural values as "neighboring," reciprocity and trust; the increasing feeling of an uncertain future; the disintegration of relationships between humans and land and traditional systems of land stewardship; and the emerging redefinition of property values and social class systems based on ownership versus non-ownership of mineral rights. However, some might view the development a bringing the community together; allowing for an increase in local decision making; helping the agricultural character to continue because of the amount of produced water that will used to sustain irrigation for livestock; and the development could result in a feeling of prosperity and increased growth of relationships between humans and the land. There is potential that these social impacts may occur within the Project Area, but the extent and magnitude are not feasibly measurable. A region issue-related study would be required to fully understand and quantify these social impacts.

It would be highly speculative and very difficult to predict the project's long-term impact on community values. Likewise, it would be difficult to assess whether implementation of the project would have any effect on religious facilities in the area.

Recreation

As discussed in the section on Recreation, hunting, fishing, sightseeing, and camping are a few of the recreational activities that occur in the Project Area and contribute to the quality of life. A decrease in recreation is not expected as a result of the Proposed Action. The acreage removed from wildlife habitat by the project facilities under the Proposed Action is not likely to adversely affect hunting and fishing opportunities within the Project Area. These activities may increase locally within the Project Area as populations of game animals and game fish rise locally during the life of the project, in responses to increased availability of surface water and forage. Increased access and human activity associated with the development may adversely affect wildlife populations that support various recreational activities. Increased access may also increase acreage that can be hunted, which was previously inaccessible to the majority of the hunters. The monetary costs associated with these local phenomena would be speculative and are therefore beyond the scope of this analysis.

Agricultural Culture

Many have concerns about the increased salinity of irrigation water. Although increase will occur in some watersheds, the costs to the agricultural communities cannot necessarily be measured in this analysis, as site specificity would be necessary to predict gains and losses to the agricultural communities. For instance, translating levels of unused vegetation into AUMs would require knowledge of the consumption of forage by livestock in a specific area. The impact of any stocking level depends on the ability of an area to withstand grazing pressure. Amounts available to livestock differ from place to place. Additionally, successful project-related reclamation can result in improved grazing and therefore increased AUM value. Residents who use irrigation are concerned about drawdown that might occur and therefore affect the water quantity, while others are grateful for the produced water. The livelihood of some rancher's livelihood has been sustained and is thriving as a result of the produced water from CBM development. These issues cause difficulties in predicting losses or gains to the agricultural industry on a project-wide level. Non-monetary gains and losses to agricultural are further discussed in the section on Land Use of Chapter 4 of this EIS.

Crime

Implementation of the project is not expected to affect crime statistics measurably for most types of crime that occur in the Project Area. In spite of an increase in CBM employment between 1999 and 2000 (Wyoming Department of Employment Research and Planning 2002), most crimes, including larceny, aggravated assault, burglary, motor vehicle theft, and robbery, decreased (Campbell County Sheriff's Department 2000) between 1999 and 2000 in Campbell County, which is where most of the CBM workers live. Simple assault was the only category that showed an increase in arrests (Campbell County Sheriff Department, 2000). Crimes by employment sector are not available in any of the counties within the Project Area; therefore, the number of arrests of CBM workers is not available.

Other studies conducted in Campbell County indicate similar trends for the period from 1990 to 2001. According to *The Analysis of Campbell County Crime Data for the Years of 1990–2001*, arrests increased between 1990 and 2001; however, the majority of these arrests were for minor offenses such as contempt of court, citations for barking dogs, trespass, admitting minors to improper places, and tobacco law violations. A small increase in arrests was attributable to possession of drugs, disorderly conduct, and drunkenness. Arrests for drug possession accounted for 4 percent of the arrests in 2001, which is not unexpected since many communities across the country are experiencing growth in drug possession. Disorderly conduct and drunkenness, usually considered low-level offenses, increased between 1990 and 2001. More serious crimes, such as aggravated assault, weapons violations, burglary and motor vehicle theft, larceny, and sex offenses did not increase from 1990 to 2002 and in some cases have declined (Beck 2002).

Property Values

Property values increase as result of high demand property and low supply. Property values within the Project Area have increased in recent years, primarily as a result of the influx of population, CBM and non-CBM related, and the value of land based on royalties associated with CBM activity. Average sales prices reported by assessors indicate that property values have increase from 5.91 to 45.47 percent within the Project area between 1999 and 2000 (Wyoming Partnership database 2002). Property values may also be affected negatively by the presence of CBM activity and associated activity (visual, traffic, and noise, for example). It would be highly speculative to quantify these effects positively and negatively given the size of the Project Area and the social factors related to property values.

Environmental Justice

This socioeconomic analysis considered disproportionately adverse effects on minority or low-income groups, including Native Americans. No potentially adverse effects that disproportionately affect Native American tribes or minority and or low-income groups have been identified. Issues related to the social, cultural, and economic well-being, and health of minorities and low income groups (environmental justice) issues were evaluated during the analysis of the Proposed Action on socioeconomic resources, surface water and groundwater quality, air quality, hazardous materials, and other elements of the human environment. No disproportionate environmental impacts were identified.

Implementing the Proposed Action would not have significant disproportionate adverse affects on the social, cultural, and economic well being, and health of minorities and low-income groups. With regard to environmental justice issues that affect Native American tribes or groups, the PRB CBM Project Area does not contain tribal lands or Indian communities, and no treaty rights or Indian trust resources are know to exist for this area. No communities within the Project Area would be likely to be physically affected by the reasonably foreseeable development of CBM. Communities outside the Project Area, which would have a low potential to be affected from a water quality perspective, include the Northern Cheyenne and Crow Reservations as well as a small Amish colony in southern Montana, just north of the Upper Tongue River Watershed. Water quality agreements and measures are discussed below with respect to environmental justice.

The Tongue River flows directly into the Tongue River Reservation and forms the eastern boundary of the Northern Cheyenne Reservation. Three regulatory agreements and processes ensure and restrict the impact to water quality. These agreements and processes include NPDES permitting regulated by WDEQ, a MOC between Wyoming and Montana, and Clean Water regulated by EPA and tribal water quality standards. These agreements and processes, described herein, limit and prevent disproportionate effects to the human and biological resources in the areas. First, as stated Chapter 2, the Companies are required to monitor and report produced water volumes and quality to WDEQ pursuant to NPDES permit requirements. Discharges are required to meet all applicable WDEQ-WQD water quality standards and regulations at all times. The Companies on a voluntary basis have also initiated and funded several studies that are intended to address the cumulative effects of the collective water discharges. Second, WDEQ and MDEQ have initiated the MOC on Montana and Wyoming Powder River Interim Water Quality Criteria. The intent of the MOC, with respect to environmental justice, is to recognize a responsibility and an opportunity to collaboratively protect water quality in the Powder River Basin to facilitate the development of CBM activities in the states. Under the MOC, the State of Wyoming recognizes Montana's downstream interests and has committed to apply certain limits on the development of CBM during the term of the cooperative effort and would work with and support Montana's efforts to develop long-term water quality standards and an equitable allocation of the assimilative capacity if one exists. The narrative regulations set forth in EPA's Clean Water Act also aim to protect and preserve water quality. Until tribes submit water quality standards to EPA, the states (Montana and Wyoming), and federal government regulate tribal water quality. Currently, the Northern Cheyenne and Crow Reservation water quality standards are subject to these regulations. However, the Northern Cheyenne has submitted numeric water quality standards for review by EPA. If EPA approves these standards, the Northern Cheyenne tribe will have its own water quality standards. These water quality standards would differentiate from the Clean Water Act in that they would be numeric as opposed to narrative and could be stricter. All CBM produced water would meet the above requirements before water-related permits could be approved. The Northern Cheyenne water quality standards are discussed in the MOC between the states and are referenced in the section of this EIS on Surface Water.

The MOC states that water quality in streams and rivers entering Montana from Wyoming will not exceed set limits for toxicity as a result of CBM produced water discharge in Wyoming. For this reason, the Upper Tongue and Middle Powder sub-watersheds would not see noticeable increase in stream flows or increased sedimentation impact to aquatic species, increased salinity due to content of produced water and little increase in hazardous levels of metals, assuming all permitting was in conformance with the state requirements.

BLM will abide by all applicable water quality standards and, consistent with applicable authority, will work in partnership with the States of Montana and Wyoming to ensure that lessees comply with the state and tribal permitting requirements. BLM will continue to acknowledge the authority and jurisdiction of the states on water quality. For this reason, water quality will be carefully regulated and impacts to fish and wildlife are expected to be limited on these reservations. Wildlife may increase locally within and outside the Project Area as populations of game animals and game fish rise locally during the life of the project in responses to increased availability of surface water and forage. Increased access and human activity within the Project Area associated with the development may result in additional wildlife migration into the reservations. This behavior would, however, be subject to the amount and timing of the human activity within the northern portion of the Project Area. Impacts to hunting and fishing are not anticipated to increase or decrease as a result of the Proposed Action as a result of the state and tribal permitting processes and or standards. Therefore, existing subsistence patterns are not expected to be altered as a result of the Proposed Action.

The Amish colony north of the Project Area and low-income populations within the Project Area are not anticipated to suffer from disproportionate adverse effects. Water quality in all areas must be in accordance to state requirements prior to approval.

Although low-income and minority populations can have increased vulnerability to environmental impacts as a result of increased stress and poor health care, the current CBM impacts are not disproportionate from the general population. Impacts related to health and safety are included in this document. The current environmental and socioeconomic CBM impacts are spread across all races, ages, and income levels. Within the Project Area, environmental regulations are enforced to protect all groups through EPA, the Montana Department of Environmental Quality, and the Wyoming Department of Environmental Quality.

Alternative 2

Alternative 2 specifically relates to methods for handling produced water and may slightly increase the land required to dispose of water. Such increase in land use may have negative visual implications ultimately affecting the "quality of life."

Alternatives 2A and 2B result in minimal change to the employment, wages, housing, infrastructure, and royalties. Because of the water handling methods emphasized in these alternatives, CBM employment will increase to 2,787 for Alternative 2A and 2,708 for Alternative 2B, primarily resulting in the construction of these facilities. Direct cumulative employment from CBM and Non-CBM development for all phases is shown on Figure 4–54 and Figure 4–55.

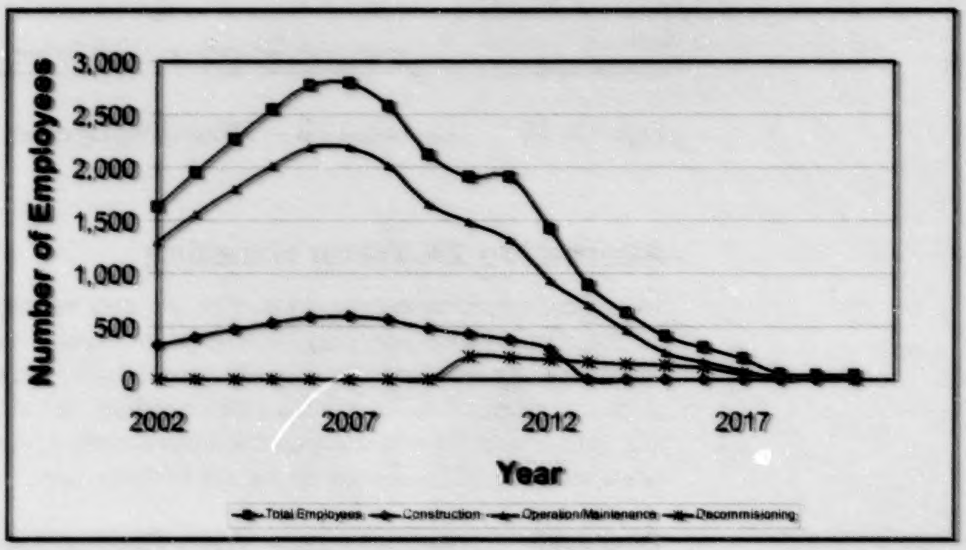


Figure 4–54 Alternative 2A — Direct Employment

Non-CBM employment will be the same as for Alternative 1. Therefore, an additional net present value of $641 million (Alternative 2A) to $632 million (Alternative 2B) in annual wages will be generated as a result of the additional employment from the water handling facilities. There may be a slight increase in infrastructure demands; however there will be an increase in traffic as a result of the water handling methods. The number of wells remains unchanged; therefore, royalties are the same as the Proposed Action. Of all the socioeconomic issues, taxes will be the most affected because of the cost of the water handling facilities. Specifically, sales tax revenues will be altered. Water handling as it applies to the cost of each method and number of each method is described below.

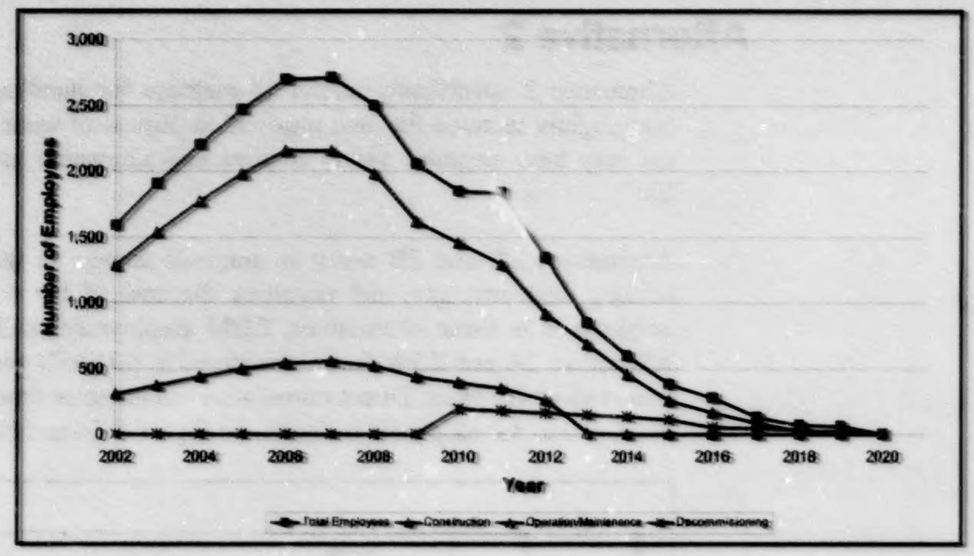


Figure 4–55 Alternative 2B — Direct Employment

Alternative 2A Water Handling

Tax revenue generated from Alternative 2A may be slightly higher than that of the Proposed Action primarily because of the number and types and amount of water handling methods. The primary water handling cost of Alternative 2A is a result of emphasis of infiltration water handling. As shown in Table 4–80, the total sales revenue generated from the water handling portion of this alternative is estimated to be $52.9 million for the life of the project.

Table 4–80 Alternative 2A — Water Handling Sale Tax Revenue

Type of Water Handling Facility	Sales Tax Generated From Water Handling Facility (millions of dollars)[2]
Surface discharge — Untreated	$3.85
Surface discharge — Active Treatment	0.0
Surface discharge — Passive Treatment	9.9
Infiltration	33.1
Containment[1]	0.62
LAD	2.0
Injection	3.5
Total	52.9

Note:
1. Operation and maintenance costs are unknown and not included.
2. Calculations are not based on net present value.
Source: CBM Operators Information Survey Results Report, 2001; Williams, 2001; and Kolin 2002.

The total sales tax generated from drilling and water handling in Alternative 2A is estimated to be $130 million for the life of the project.

Alternative 2B Water Handling

Tax revenue generated from Alternative 2B is slightly higher than under the Proposed Action and Alternative 2A because of the number of surface discharge and infiltration water handling methods. As shown in Table 4–81 the total sales tax revenue generated from water handling in this alternative is estimated to be $60.7 million for the life of the project.

Table 4–81 Alternative 2B — Water Handling Sales Tax Revenue

Type of water handing facility	Sales Tax Generated from Water Handling Facility (millions of dollars)[2]
Surface discharge — Untreated	$2.77
Surface discharge — Active Treatment	16.8
Surface discharge — Passive Treatment	10.4
Infiltration	23.6
Containment[1]	1.8
LAD	2.1
Injection	3.3
Total	60.7

Note:

1. Operation and maintenance costs are unknown and not included.
2. Calculations are not based on net present value.

Source: CBM Operators Information Survey Results Report, 2001; Williams, 2001; and Kolin 2002.

The total sales tax generated from the drilling and water handling of Alternative 2B is estimated to be $138 million for the life of the project.

The two compression options for these alternatives include electrification of 50 percent of the booster compressors, with the difference using gas-fired booster compression and electrification of 100 percent of the booster compressors. The cost associated with these alternatives varies depending on the price of gas versus the price of electricity. For this analysis, if the price of electricity is assumed to be $0.0372/kilowatt hour (kWh) (Browne 2001) and a fully loaded engine can produce the equivalent of .746 kWh, then electric generation would cost approximately $0.02775 per horsepower hour.

Assuming the gas-fired engine requires 0.01 mcf per horsepower hour (Zavadil 2001) and gas is at $2.25 per mcf (Wyoming Division of Economic Analysis, 2001), gas-fired compression would cost approximately $0.02250 per horsepower hour. Therefore, the price of gas would represent a 19 percent savings. Capital costs for motors, generators, and engines are included in this analysis. Additionally, because the gas is used on these compressor engines, there is some savings to the Companies from the basis differential, gathering and compression rates, transport deductions, and royalty and ad valorem savings, which ultimately result in lower net fuel cost. For instance, the fuel cost might be $3.00/mmbtu; however, after these deductions, the true cost for fuel is only $1.32/mmbtu (Keanini 2001b). Natural gas is a more economical option because of the number of costs that the operators do not incur. One of the costs that is not incurred is the payment of royalties as a result of leasehold use. The federal government does not retain royalties when the natural gas is used by the leaseholder to fuel natural gas booster pumps. It is estimated that if 136,656 mmbtus are required per year per engine (Keanini 2001b), $5.59 million to $6.71 million would be lost in royalties per 2,000-horsepower engine over the life of the project (assuming the net present value, discounted at 8 percent). However, even if royalty costs were included in the comparison between natural gas and electricity, natural gas would continue to be more economical for the operators (Keanini 2001b).

For this analysis, given the current projected price of natural gas and electricity, natural gas booster compressor units would be more economical to the operators but would result in a loss of royalties for the federal government. Electric booster compression units add no economic value to the operators or the community.

Alternative 3 — No Action

Under the No Action Alternative, additional natural gas drilling would not be authorized on federal leases within the Project Area. However, drilling could still occur on state and private land. The No Action Alternative would result in approximately 1,481 fewer jobs created during the peak activity years in the Project Area over the life of the project and therefore approximately $196 million in annual income within the counties of the Project Area. Figure 4–56 identifies the locations of CBM and non-CBM wells by jurisdiction.

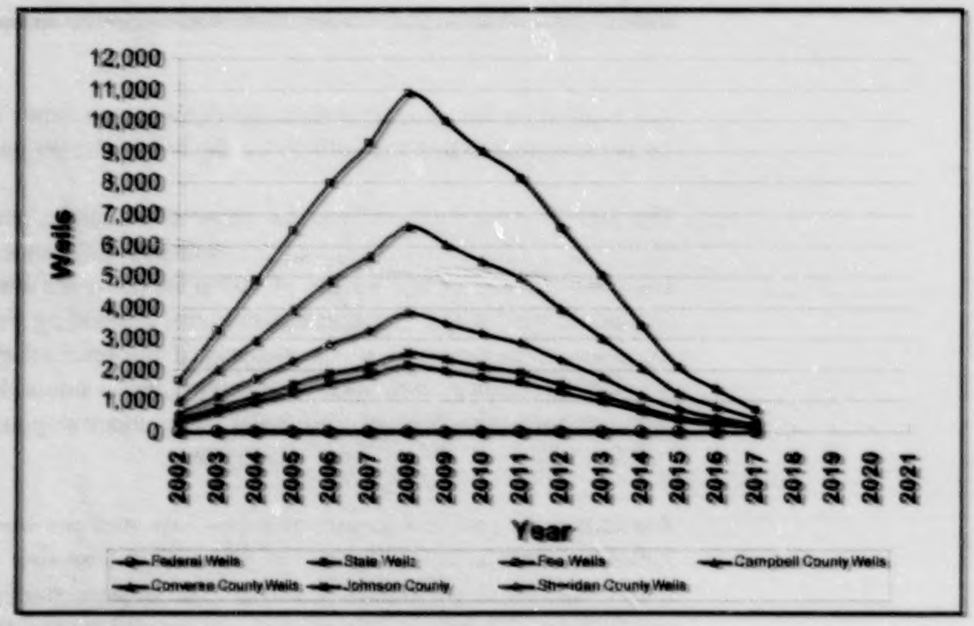


Figure 4–56 Alternative 3 — Number of Wells by Jurisdiction and Year

Expenditures made by the Companies and local tax revenues would be reduced substantially because 23,909 fewer CBM wells and 1,885 non-CBM wells would be drilled under this alternative, which also decreases the revenue generated from other facilities as well. In addition, the costs and benefits of the project directed to Campbell, Converse, Johnson, and Sheridan counties would be reduced relative to the Proposed Action and Alternative 2. Federal mineral royalties from CBM alone would result in $1.7 billion less in sales value than in the Proposed Action. With no additional federal wells, no additional federal royalties would be available and no associated distribution to the counties.

Tax revenue generated from Alternative 3 is lower than the Proposed Action and Alternatives 2A and 2B, primarily a result of the decreased number of wells, which therefore decreases the number of water handling facilities. As shown in Table 4–82, $24 million tax will be generated from water handling. The total sales tax generated from drilling and water handling is estimated to be $82 million for the life of the project. The severance tax generated from this alternative is estimated to be $1.1 billion for the life of the project. The ad valorem tax generated from this alternative is estimated to be $1.2 billion for the life of the project. Figure 4–57 and Figure 4–58 illustrate the percentage of royalties and taxes for Alternative 3 CBM and Non-CBM wells.

Additionally, not drilling federal wells now may result in future negative production rates from federal minerals. Drilling on private and state minerals would likely result in depletion of federal minerals, and therefore potential federal royalties, within portions of the Project Area. Modeling by Joe Meyer, BLM hydrologist, indicated that in an undrilled area within the project Area, 9 to 22 pounds per square inch (psi) of pressure drawdown would occur in as much as 1.5 miles from the boundary of the producing well after 18 months of production (BLM 2001b). Such significant pressure depletion is considered large and extensive (BLM 2001b). According to the same report, it is believed that undrilled federal acreage, specifically within the Upper Belle Fourche River subwatershed, may have been so severely depleted that an economic well is no longer feasible. It is anticipated that depletion would continue to worsen and spread over a wider area within a portion of the Project Area as CBM development continues (BLM 2001b).

Table 4–82 Alternative 3 — Cost and Sales Tax Revenue

Type of water handing facility	Sales Tax Generated From Water Handling Facility (millions of dollars)[2]
Surface discharge — Untreated	$10.4
Surface discharge — Active Treatment	0.0
Surface discharge — Passive Treatment	1.04
Infiltration	8.77
Containment*	1.2
LAD	0.45
Injection	21.5
Total	24.0

Note:

1. Operation and maintenance costs are unknown and not included.
2. Not calculated using net present value.

Source: CBM Operators Information Survey Results Report, 2001; Williams, 2001; and Kolin 2002.

Like Alternative 1 and 2, Alternative 3 would not have significant adverse Environmental Justice affects on the social, cultural, and economic well being and health of minorities and low-income groups for the reasons stated under Alternative 1.

Cumulative Effects

Economic Consequences

The estimated cost of each alternative is provided in Table 4–83. The costs were generated using cost assumptions provided in Table 4–84 and Table 4–85. For this analysis, the following costs were not included in this analysis: land acquisition and holding; royalties; permitting; engineering; corporate overhead; management; taxes; interest; return of and return on investment; and time value of money. The costs that are provided were used to estimate the socioeconomic impact to the affected communities.

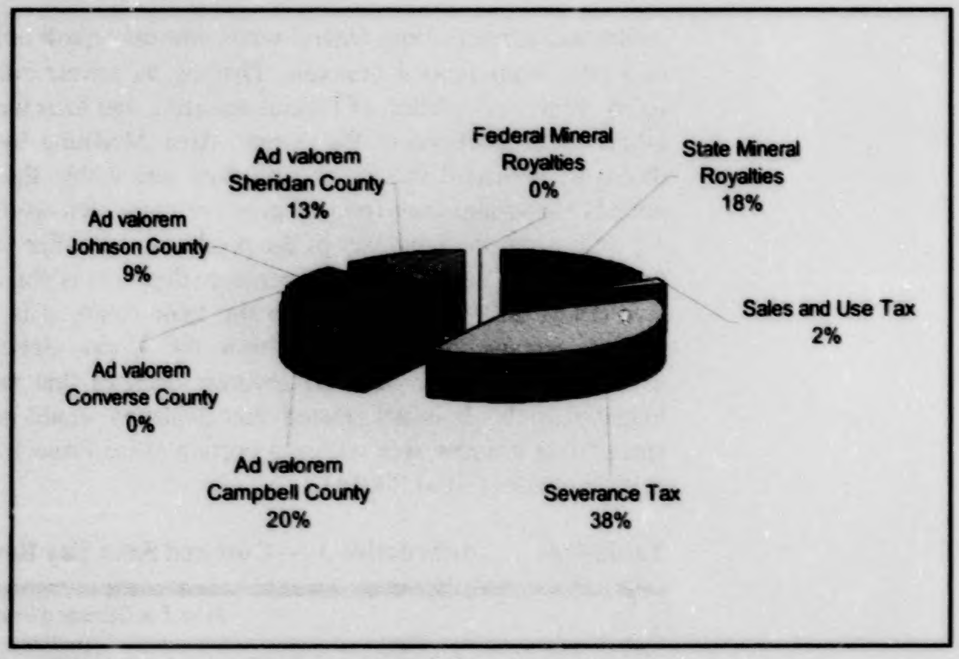


Figure 4–57 Alternative 3 — Net Present Value of Taxes and Royalties from CBM Wells

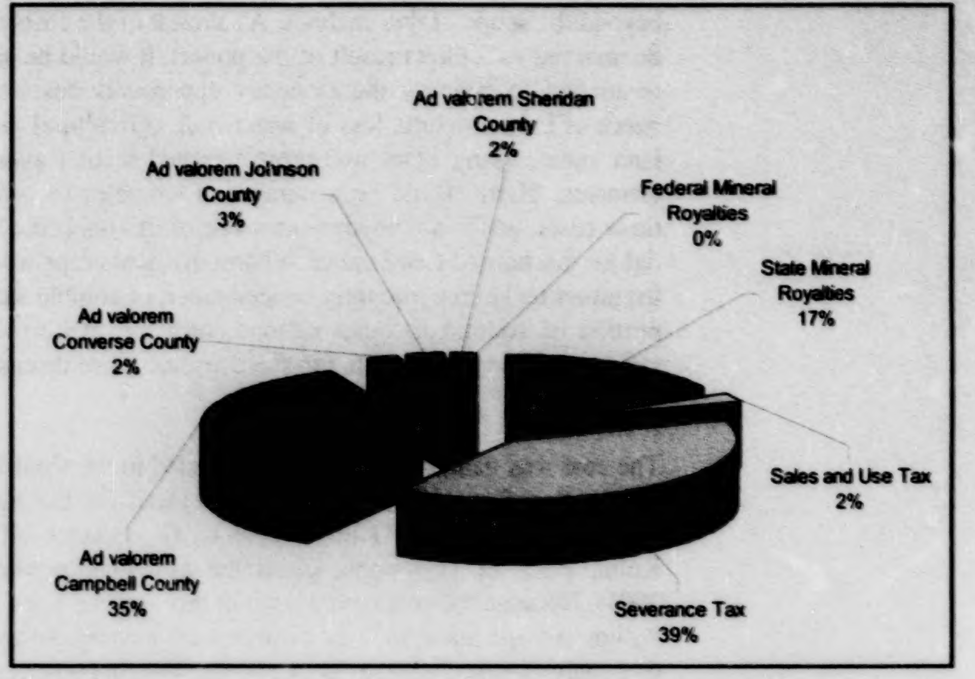


Figure 4–58 **Alternative 3 — Net Present Value of Taxes and Royalties from Non-CBM Wells**

Table 4–83 **Estimated Direct Cost of Each Alternative over the Life of Project ($ Millions)**

Source	Alternative1	Alternative 2a	Alternative2b	Alternative3
Wells				
Capital Costs	4,172	4,172	4,172	1,653
Operation and Maintenance	12,940	12,940	12,940	5,128
Reclamation	159	159	159	57
Water Handling[1]				
Capital Costs	260	326	374	114
Operation and Maintenance	1,180	1,270	1,501	630
Reclamation	132	168	148	56
Total[2]	18,843	19,035	19,294	7,638

Note:

1. Water handling includes Surface discharge (Untreated, Active Treatment and Passive Treatment), Infiltration, Containment, LAD, and Injection.
2. Estimations do not include costs for the following: land acquisition and holdings; royalties; permitting; engineering; corporate overhead; management; taxes; interest; depreciation; return of and return on investment; and time value of money. Costs are not calculated in Net Present Value.

Source: CBM Operators Information Survey Results Report, 2001; Williams, 2001; and Kolin 2002.

Costs associated with increased maintenance of infrastructure, loss of water, soil, agricultural production, wildlife, and land value were not assessed as they are beyond the scope of this analysis. As a result of the costs that would or would not be incurred as a direct result of the project, it would be arbitrary and speculative to attempt to quantify the monetary opportunity costs associated with maintenance of infrastructure, loss of water, soil, agricultural, production, wildlife, and land value. Many other non-project related factors alter the economics of the elements. There would be a number of variables to consider when calculating these costs, which are beyond the scope of this analysis. For example, the potential for discharged CBM water to harm irrigated crops would depend on the crop, irrigation technique, the total concentration of soluble salts, and its relative proportion of sodium to other cations (such as calcium and sodium). The non-monetary opportunity costs for these resources are discussed in the relevant sections.

The cost was generated using data provided in the Coal Bed Methane Operators Information Survey Results Report, prepared for the Eastern Research Group, Inc. and for EPA (O&G Environmental Consultants 2001). Additionally, Mike Kolin, P.E., of Greystone, generated estimated project-related costs. (Kolin 2001). Because the conceptual level of this analysis does not present site-specific design and operation, the cost estimates are incomplete and are only for comparative analysis based on a series of assumptions. In instances where cost was speculative, it was not included in the analysis (such as roads, pipelines, compressors, electric generation, and other facilities associated with wells).

Table 4–84 Estimated Direct Costs of Drilling and Reclamation for CBM and Non-CBM Wells

Drilling activities	Estimated cost/unit for CBM well	Estimated cost/unit for non-CBM
Drilling and completion	$60,000 per well[1]	$500,000-2,500,000[2]
Well Infrastructure Cost per well[3]	$23,500 per well	$50,000[2]
Additional pod infrastructure[4]	$21,000 per well[1]	$50,000-75,000[2]
Gathering Fees per[5]	$20,000 per well[1]	$10,000 per well[2]
Operation and Maintenance[6]	1,240 per month per well[1]	$1,000-$2,500 per month per well
Reclamation	$700 per acre[7]	$3000 per acre[2]

Notes:

1. Generated using coal Bed Methane Operators Information Survey Results, prepared for the Eastern Research Group inc. and for the EOA. O&G Environmental Consultants 2001.
2. Non-CBM estimated costs by D. Chase, BLM Reservoir Management Group.
3. Well infrastructure costs include telemetry equipment, pumps, and doghouse.
4. Additional pod infrastructure cost includes pod/compressor building, gas piping, and electricity.
5. Pipeline fees are costs to move gas from well head to plant.
6. Operating costs include lifting costs to wellhead.
7. Provided by Williams 2001.

Table 4–85 Estimated Cost of Water Handling Facilities

Water Handling (Includes labor)	Capital Cost of Construction cost per facility	O&M ($/bbl)	Reclamation cost per facility
Surface Discharge	$45,000	$0.05[1]	$40,000
Infiltration	$72,000	$0.06[1]	$44,000
Containment	$1,200,000	Unknown	$400,000
LAD	$500,000[1]	$0.02[1]	$3,000
Injection	$90,000[1]	$0.06[1]	$9,000

Note:
1. Generated using Coal Bed Methane Operators Information Survey Results Report, prepared for the Eastern Research Group Inc and for the EPA. O&G Environmental Consultants 2001.

Sources: CBM Operators Information Survey Results Report, 2001; Williams, 2001; and Kolin 2002.

Alternative 1

Although the cumulative economic value of CBM development under this alternative is very large, the cumulative workforce required for the project is estimated to require approximately 643 employees for construction, 4,960 for operation and maintenance, and 246 for reclamation during peak activity years (2007 and 2009). The highest peak activity would be in 2007 and would necessitate 5,579 employees. It is anticipated that 300 of these jobs would be filled from the local labor force. Additional workers would come from outside the region, or the unemployed labor force would obtain the necessary skills to fill the positions. Over the life of the project, the net present value of the annual payroll is estimated to be $1.2 billion. Employment opportunities will likely be greatest during the first 10 years, and would gradually decrease over the life of the project (Figure 4–59).

Because the local labor force would likely occupy new jobs, the increased population growth of the communities is not anticipated as a result of the Proposed Action. However, during peak activity years, short-term effects from a 7 percent incremental increase in population may be substantial. It is not anticipated that water systems, solid waste disposal, public schools, law enforcement, fire protection, or medical facilities would incur substantial additional effects from the Proposed Action. The local counties are accustomed to absorbing fluctuations in mineral development, which cause cycles of increasing and decreasing demands for workers, housing, and community services. Much of the infrastructure required for the current population has been created and would sustain the current population.

In addition to salaries generated by the project, extra revenue would filter to county levels through federal royalties, local ad valorem taxes, and sales and use taxes. Based on projected market prices, it is estimated that cumulative federal royalties from CBM would total $2.5 billion and $337 million from non-CBM wells (net present value discounted at 10 percent) over the life of the project. Approximately half would be paid to the State of Wyoming and half to the federal government. State mineral royalties, sales and use tax, severance tax, and ad valorem taxes would generate $3.2 billion in revenue from CBM wells and $688 million from non-CBM wells to be distributed by the state and counties, for schools, roads, and other community infrastructure.

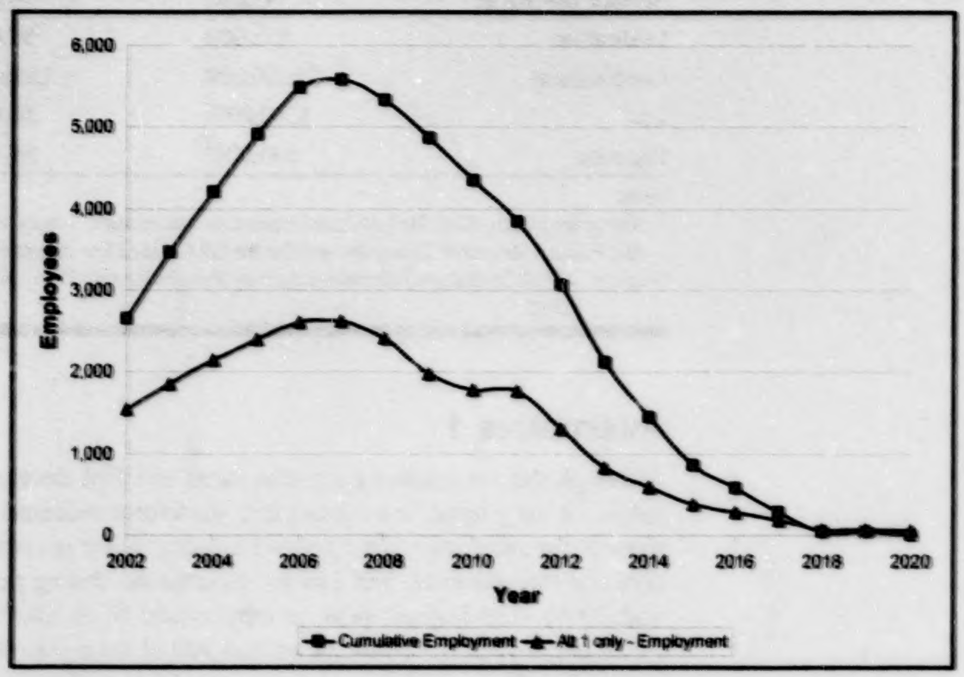


Figure 4–59 Alternative 1 — Cumulative Employment

Figure 4–60 and Figure 4–61 illustrate the cumulative percentage of royalties and taxes from existing development as well as development from Alternative 1 CBM and non-CBM wells.

The existing CBM and non-CBM development has already affected communities with in the Project Area; further development would maintain the current impacts to the quality of life. For some, the sustained employment and economic development as a result of the Proposed Action may be viewed as a positive impact to quality of life. For others, the environmental and social impacts disclosed here may be viewed as a negative impact on the quality of life. Particularly, CBM related existing and potential water quantity and quality issues and the potential impacts to the agricultural community are of concern. For some, CBM produced water is beneficial because of the increased quantity for irrigation that would not be available without CBM development. For others, concerns of potential degradation of water quality and potential drawdown affects may impair the quality of life. The latter issue will be primarily regulated by the MOC between the States of Montana and Wyoming and the water quality thresholds and criteria being prepared for the Montana Board of Environmental Review and Northern Cheyenne Tribe.

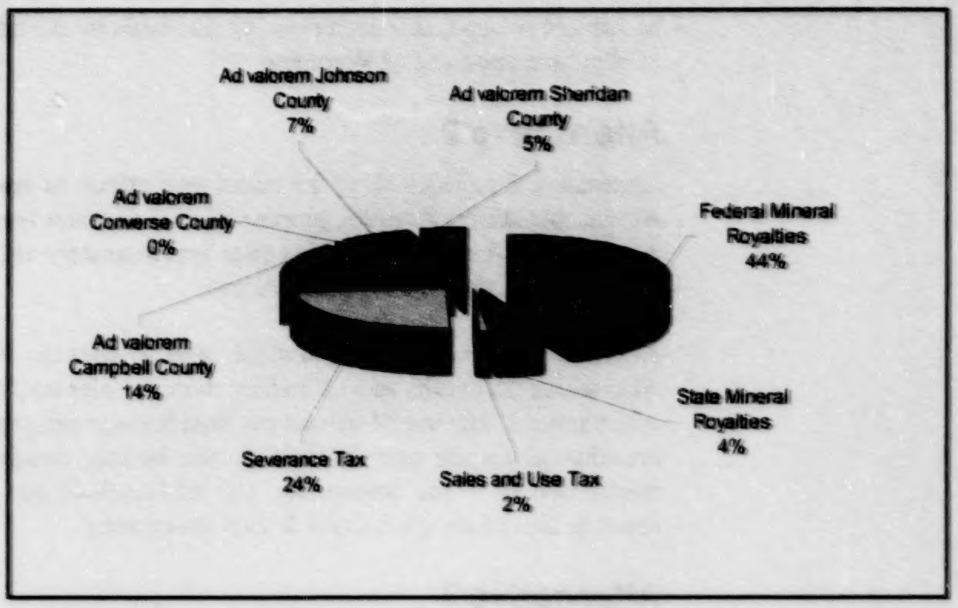


Figure 4–60 Alternative 1 — Cumulative Net Present Value of Taxes and Royalties of CBM Wells

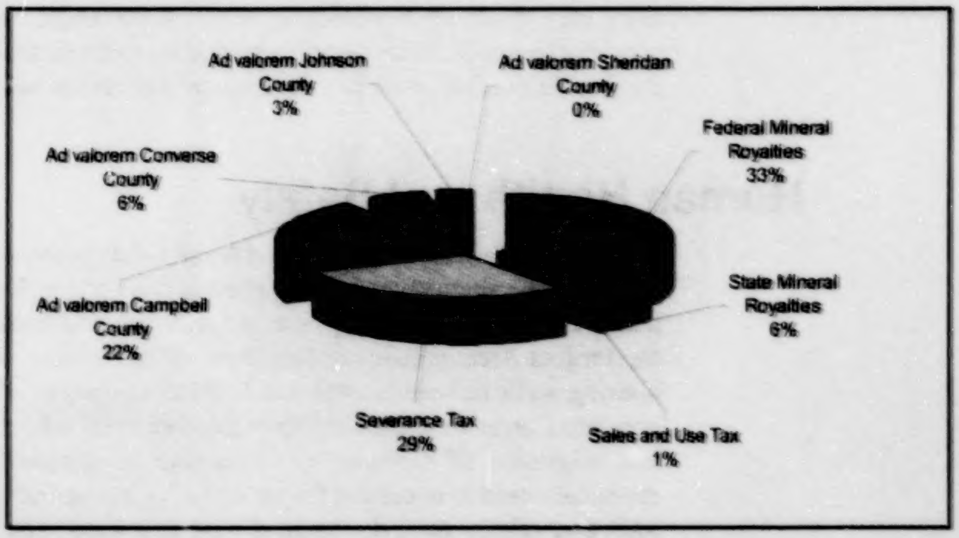


Figure 4–61 Alternative 1 — Cumulative Net Present Value of Taxes and Royalties of non-CBM Wells

Implementing the Proposed Action would have cumulative effects on social, cultural, and economic well being and health of minorities and low-income groups. With regard to environmental justice issues affecting Native American tribes or groups, the Powder River Basin Oil and Gas Project Area contains no tribal lands or Indian communities, and no treaty rights or Indian trust resources are known to exist for the area. Environmental effects associated with water quality north of the Project Area on or near the Crow and Northern Cheyenne Reservations will be subject to applicable water quality standards by the tribes, EPA, and the State of Montana and State of Wyoming.

Alternative 2

Alternative 2 includes all of the cumulative effects as described for the Proposed Action, but differs from the proposed action in water handling and compression. Alternative 2A and 2B would require approximately 182 and 84 additional employees than under the Proposed Action.

Alternative 2A results in $5.7 million more in sales tax from water handling, and Alternative 2B results in $7.8 million more in sales tax from water handling than Alternative 1. The use of natural gas fired booster compressors proves to be more economical for the operator and electric booster compressors provide no economic benefit to the community. Use of leasehold gas for compression would result in loss of royalties to the federal government.

Alternative 3

Under this alternative, no additional wells would be drilled on federal lands. Approximately 1,481 new jobs would be created under Alternative 3, resulting in about $196 million in personal income. Implementation of Alternative 3 would result in a complete loss of all the federally related benefits and costs described in the Proposed Action because no federal royalties would be collected and their associated distribution would not occur. Additionally, not drilling federal wells now may result in future negative production rates on federal minerals because of the depletion of minerals from drilling on state and private lands.

Human Health and Safety

The potential effects on human health and safety associated with implementation of any of the alternatives are addressed in this section. Potential effects to human health and safety that could be associated with additional CBM development in the Project Area include concentrations of methane in water wells or structures housing wells that are located near CBM development areas, methane seepage in populated areas near the outcrop or in other areas where geologic conditions allow migration of methane, contamination of drinking water aquifers by the chemicals used in hydraulic fracturing (if hydraulic fracturing is used), effects of SAR and salinity from discharge of produced water, and ruptures of pipelines. In addition, effects to health and safety could arise from the use of hazardous materials and pesticides, spills, illegal dumping, potential for an increase in traffic accidents on public roads, and health effects associated with noise and air emissions from project-related vehicles, and fugitive dust from roads and from application of dust control treatments such as magnesium chloride to roads.

It was assumed that, for any of the alternatives, the CBM development operations in the Project Area would comply with state and federal regulations, including the Resource Conservation and Recovery Act (RCRA), the Occupational Safety and Health Act (OSHA), the Clean Water Act (CWA), and the Clean Air Act (CAA). The BLM requires notification of all hazardous materials to be used on

340

BLM and FS lands for CBM development in the Project Area and is responsible for all releases of hazardous materials on these lands.

Safety requirement for well operations are also specified under 43 CFR Ch. II, subpart 3162.5 – Environmental Obligations. This regulation requires the approval of a drilling and operations plan that addresses the applicable procedures to be employed for protection of environmental quality, including control and removal of wastes, spill prevention, fire prevention and fighting procedures, and safety precautions. The Companies would develop emergency plans that would address all potential emergencies, including fires, employee injuries, emergency response, and chemical releases, among others. Employees and subcontractors would be trained in the storage, handling, and disposal of hazardous materials, and in implementation of the safety procedures in the emergency plans.

The Companies would also take measures to protect the public, livestock, and wildlife from hazards at CBM-related facilities. For example, warning signs would be posted around facilities, as required by regulations. In addition, compressor stations would be fenced and gated.

Alternative 1

Under implementation of Alternative 1, there would be minimal additional short-term and long-term risks to human health and safety associated with potential methane migration and seepage, pipeline ruptures, and increased vehicular traffic, as described in the following subsections.

Methane Migration and Seepage

Direct impacts from the additional CBM development under the Proposed Action include potentially increased risks of methane seepage, fires, or explosions. Methane is not biologically toxic and does not cause cancer, but high concentrations in confined spaces can displace oxygen and present a danger of fire or explosion.

Methane gas can reach the surface by naturally occurring seepage along fault lines, fractures, or sandstone layers in areas where coal beds are shallow. Gas migration could be enhanced during CBM development in areas along the coal outcrop. Non-CBM wells may provide pathways for migration of methane if the casings or plugs are inadequate or faulty or lack isolation through the coal horizons. The potential for migration of methane in CBM wells is minimized or prevented by the use of the current CBM industry standards for cementing and casing that isolate or protect all zones from gas or fluid migration. Water wells are frequently screened over multiple aquifer zones, which could provide pathways for migration of methane.

As population and the density of residential development increase over time, the potential for additional CBM development and any associated methane seeps, fires, or accidents to affect residential land uses and human health and safety would be likely to increase. Risks to human health and safety would rise proportionately with the number of CBM wells and with increased proximity of CBM wells to other land uses, primarily residential uses. Residential properties near the proposed CBM facilities would be most sensitive to these risks.

Risks from methane associated with oil and gas wells, including CBM wells, would be controlled through the BLM-mandated conditions of approval for the APD that address well conditions, casing, ventilation, and plugging procedures appropriate to site-specific CBM development plans. In addition, the Companies have developed emergency plans and employee training programs that address fire prevention and control measures.

Experience in the PRB has shown that few cases of methane seeps that involve potentially explosive concentrations have occurred. The extent and intensity of methane migration and seepage associated with the proposed action would depend on site-specific conditions. Although some potential for increased migration and seepage of methane exists in the Project Area, increases in risks to human health and safety are not anticipated with the additional CBM wells.

Implementation of the Proposed Action is unlikely to increase the risk of coal fires in the Project Area. Spontaneous combustion of coal is not likely to be caused by CBM development under Alternative 1. The potential for coal fires associated with each of the alternatives is analyzed in Geologic Hazards discussions in Chapters 3 and 4.

Contamination of Drinking Water Aquifers by Hydraulic Fracturing

Hydraulic fracturing, if used to complete CBM wells, is not likely to have any effect on groundwater quality. Although the potential impacts on underground sources of drinking water from hydraulic fracturing of CBM wells are not well known, no cases of groundwater contamination associated with hydraulic fracturing of CBM wells have been substantiated (EPA 2002a). Only a limited area surrounding the CBM well bore is affected by this procedure. Commonly used fracturing fluids do not contain environmentally hazardous substances. None of the constituents used in hydraulic fracturing of CBM wells have been documented to affect water wells or groundwater supplies in the PRB.

Where CBM wells are drilled in close proximity to existing water wells, the water quality in the existing wells may be temporarily affected by increased sediments, fines, and odors. These effects are expected to be temporary, clearing up after a time. Site-specific monitoring data would be needed to evaluate whether an aquifer or water well has been impaired by hydraulic fracturing (EPA 2002).

Based on a 1998 survey of state oil and gas agencies by the Ground Water Protection Council (EPA 2002a), no impacts to existing drinking water wells had been documented from hydraulic fracturing. An analysis of the potential for contamination of drinking water aquifers by the chemicals used in the hydraulic fracturing fluids, as well as monitoring, are addressed in the Groundwater sections. Implementation of the MMRP as outlined in Appendix D would minimize the potential for impacts to groundwater quality or contamination of drinking water aquifers.

BEST COPY AVAILABLE

342

Impacts of Sodium Adsorption Ratio in Produced Water

It is unlikely that surface discharges of produced water with high SAR values would affect drinking water supplies, as discussed in the sections on Groundwater and Surface Water.

The State of Wyoming has established water quality standards for surface waters for the protection of both human health and aquatic life. Aquatic life standards are more stringent than drinking water standards for some constituents. If produced water does not meet Wyoming's quality standards, it cannot be discharged to waters of the state; however, Wyoming has not currently established numerical standards for SAR, salinity, or sodium. Potential impacts to surface water quality on tribal lands associated with the Proposed Action are addressed in the sections on Surface Water. Impacts to fish from increasing salinity in surface drainages associated with the proposed action are addressed in the section on Aquatic Species.

Pipeline Ruptures

Additional CBM development may increase the potential for leaks or ruptures of gas flowlines or pipelines. Most ruptures occur when heavy equipment accidentally strikes the pipeline while operating in close proximity. These ruptures may result in a fire or explosion if a spark or open flame ignites the escaping gas.

Materials used in the pipelines would be designed and selected in accordance with applicable standards to minimize the potential for a leak or rupture. Pipeline markers are posted at frequent intervals along the pipelines to warn excavators and to reduce the risk of accidental rupture from excavating equipment. The Companies would monitor the pipeline flows by either remote sensors or daily inspections of the flow meters. Routine monitoring reduces the probability of effects to health and safety from ruptures by facilitating the prompt detection of leaks. If pressure losses were detected, the wells would be shut in until the problem is isolated and addressed.

Approximately 20,474 miles of new pipeline would be associated with the proposed action. Based on a statistical average of one safety incident per year per 5,445 miles of total pipeline (BTS 2002), four additional pipeline safety incidents (including ruptures) may occur per year over the life of the project. The specific locations of the proposed pipelines are not yet defined; therefore, detailed estimates of the risk of pipeline ruptures in the Project Area are not quantifiable at this time. Under implementation of the proposed action, there would be minimal increased risks to human health and safety associated with potential pipeline ruptures in proportion to the increased number of CBM-related facilities.

Use of Hazardous Materials and Pesticides, Spills, and Illegal Dumping

Impacts to human health and safety could arise from the hazardous materials and herbicides stored and used for CBM well drilling and production, primarily from the potential for accidental spills or illegal dumping of hazardous materials or wastes.

343

Federal and WOGCC regulations address the transport, storage, and disposal of hazardous materials or wastes. Assuming that the operators comply with the regulations, these rules would minimize the potential for spills or contamination of surface drainages or groundwater or releases of air emissions. Well operations are also regulated under 43 CFR Ch. II, Subpart 3162.5 – Environmental Obligations. This regulation requires approval of a drilling and operations plan that addresses the applicable procedures to be employed to protect environmental quality, including control and removal of wastes, spill prevention, fire prevention and fighting procedures, and safety precautions.

Regulations for handling, storage, and disposal of hazardous materials are codified at 49 CFR Parts 171 and 179. EPA requires a Spill Prevention Control and Countermeasures Plan (SPCC) under 40 CFR Part 112 for storage of large quantities of petroleum products, such as fuels. Oil spills must be reported to the EPA National Response Center as required by 40 CFR Part 110. Federal and state operating and reporting requirements include provisions to clean up and mitigate spills or releases of chemicals, product, or wastes.

BLM policy requires identification of the chemicals that would be used, stored, and produced during construction and operations. Hazardous Substances Management Plans would be developed and implemented by the Companies to prevent spills and illegal dumping of hazardous substances, pesticides, and wastes.

It is assumed that the storage, use, and transport of these materials and the disposal of wastes generated would comply with all pertinent federal regulations. The specific locations of the proposed storage areas for these hazardous materials are not yet defined; therefore, detailed estimates of the risks of spills are not quantifiable at this time. The hazardous materials typically used in CBM development and the estimated quantities that would be stored in the Project Area are listed in Table 4–86.

Hazardous materials commonly used in CBM development include ammonia, gasoline, diesel fuel, motor oil, greases and lubricants, solvents to clean equipment, heat transfer fluids such as antifreeze (glycols), paint, sand, fertilizers, and herbicides (weed killers). Other than the minimal amounts of herbicides that are used to control noxious weeds, pesticides are not generally used for CBM development. The BLM or county where the CBM facilities would be located would approve the type of herbicides and their planned uses at a specific site and time of application. Additional hazardous materials that are used for CBM development include sodium hydroxide and buffers (to regulate the pH of the drilling mud), acids for well stimulation, and surfactants (soap-like materials to remove carbon dioxide during gas processing), inert gases (not toxic, flammable, or explosive), and welding and cutting materials.

Typical wastes generated by oil and gas development include produced water, oilfield production fluids (drilling muds and used fracturing fluids), crude oil and condensate, and soils contaminated with relatively low concentrations of petroleum products. Disposal of some quantities of crude oil or condensate typically involves the sale of these wastes to a waste oil recycler. Contaminated soils are generally disposed of in an approved landfill used for nonhazardous wastes or are

344

BEST COPY AVAILABLE

treated on site (through land farming or aeration) if permitted by the local regulatory agencies.

Table 4–86 Typical List of Hazardous Chemicals Used per CBM Well

Hazardous Chemical	Typical Use	Approximate Quantity Used
Hydrochloric acid	Well stimulation	<1 gallon
Sodium hydroxide	pH control	50-250 pounds
Soda ash	pH control	50-250 pounds
Sodium bicarbonate	pH control	50-250 pounds
Lime	Drilling material	50-250 pounds
Cement	Well completion and plugging	10,000-25,000 pounds
Calcium chloride	Cement additive	200-500 pounds
Cellulose polymer	Cement additive	5-20 gallons
Cellulose flakes	Cement additive	25-75 pounds
Bentonite	Cement additive	600-1,500 pounds
Pozzalans	Cement additive	5,000-15,000 pounds
Ammonium bisulfite	Corrosion inhibitor	5-25 gallons
Oxygen scavenger	Corrosion inhibitor	5-25 gallons
Aluminum stearate	Defoaming agents	0-50 gallons
Mixed alcohols	Defoaming agents	0-50 gallons
Sodium acid pyrophosphate	Detergent	0-50 gallons
Class C explosive	Charged well jet perforating gun	0-100 pounds
Class A explosive	Detonators	0-100 pounds
Partially hydrolized polyacrylamide	Filtration control agents	0-100 pounds
Polyanionic cellulose	Filtration control agents	0-100 pounds
Diesel	Fuel	1,000-3,000 gallons
Gasoline	Fuel	100-200 gallons
Cellulose and guar derivatives	Gelling agents	0-50 pounds
Ethylene glycol	Heat transfer fluid (coolant)	25-250 gallons
Nitrogen	Inert gas	0-1,000 pounds
Hydraulic fluids	Lubricants	50-200 pounds
Mica	Circulation materials	0-1,000 pounds
Sawdust	Circulation materials	0-1,000 pounds
Paint & paint thinner	Reduce corrosion	5-25 gallons
Pipe joint compound	Sealant	10-25 gallons
Carbon tetrachloride	Solvent	<1 gallon
Methanol	Solvent	0-55 gallons

Human health and safety would likely be protected by the Companies' compliance with all applicable federal and state laws governing safe operation of natural gas facilities. In addition, the Companies have developed emergency plans and employee-training programs that address spill prevention and control measures for hazardous materials and wastes. Impacts to human health and safety from hazardous materials, pesticides, and wastes typically associated with CBM development are expected to be unlikely.

Increased Vehicular Traffic

Implementation of the proposed action may result in an increase of 25 percent or more in traffic for some of the public roads in the Project Area, along with proportionate increases in noise and air emissions from project-related vehicles, fugitive dust from roads, and risk of traffic accidents. For the Proposed Action, impacts to human health and safety associated with the noise, vehicle emissions, and fugitive dust associated with increased vehicular traffic during construction and operation of CBM-related facilities are expected to be unlikely. Noise, vehicle emissions, and fugitive dust are addressed in the section on Air Quality and

345

Climate. The estimated increases in daily traffic for the Proposed Action are analyzed in the section on Transportation.

The specific locations of the proposed wells and access roads are not yet defined; therefore, site-specific estimates of increases in vehicular traffic and the associated potential risks of accident for the public roads in the Project Area are not quantifiable at this time. Implementation of the Proposed Action would result in significant increases in vehicular traffic on some public roads, with a proportionate increase in the risk of traffic accidents, as addressed in Section 4, Transportation.

Magnesium Chloride

Under implementation of Alternative 1, potential effects to human health and safety are unlikely to occur from the use of magnesium chloride for dust suppression on CBM-related roads. Some counties in the Project Area and some of the Companies occasionally use magnesium chloride to control dust near residences, or for deicing bridges and tunnels. In general, one application of magnesium chloride would control dust for up to 1 year.

EPA and the State of Wyoming have approved use of this chemical on public roads, with appropriate application procedures. Based on a long history of not generally producing adverse lung or toxic effects, no specific airborne exposure limit is currently established for workers using this chemical. Magnesium chloride is considered a "particulate not otherwise classified" in defining the maximum allowable air concentrations to protect workers, and is therefore considered an "inert" or "nuisance" dust.

Although not highly toxic, any dust in sufficient concentration will have adverse effects. High concentrations of magnesium chloride are a minor irritation to eyes and skin, and inhalation may cause mild irritation to the mucus membranes. Ingestion of high amounts can cause abdominal pain, vomiting, diarrhea, and, under some conditions, depression of the central nervous system. Hypersensitive persons may suffer additional adverse reactions.

Impacts to human health and safety from the use of magnesium chloride for dust control on roads associated with implementation of the proposed action are expected to be unlikely.

Alternatives 2A and 2B

Under implementation of Alternatives 2A and 2B, the number of new wells, well pads, pipelines, and roads would be the same as described for Alternative 1. The potential effects to human health and safety associated with implementation of Alternatives 2A and 2B would be similar to those described for Alternative 1.

Alternative 3

Under implementation of Alternative 3, development of non-federal CBM wells would continue on non-federal lands in the Project Area. Fewer wells would be drilled, fewer well pads, pipelines, and roads would be constructed, and the total

346

number of CBM facilities would smaller under implementation of Alternative 3. The estimated increases to average daily traffic under Alternative 3 would be more than 25 percent compared with the existing average daily traffic for some of the roads in the Project Area. Under implementation of this alternative, there would be minimal additional risks to human health and safety associated with potential methane migration and seepage, similar to those described for Alternative 1. There are 8,546 miles of new pipelines associated with Alternative 3 and an associated potential for 1.5 additional pipeline safety incidents (including ruptures) per year over the life of the project.

Because there would be fewer new facilities under implementation of Alternative 3 compared with Alternative 1, the potential risks to human health and safety would be reduced proportionately. Long-term effects to human health and safety would be minimal from implementation of Alternative 3.

Cumulative Effects

Long-term human health and safety effects to the residents of properties adjacent to the major access roads within the Project Area would be minimal. These minimal risks would result from generation of increased traffic, noise, air emissions, and fugitive dust from project-related vehicles associated with any of the alternatives. The risk of traffic accidents associated with the additional vehicular traffic would increase for any of the alternatives. Human health and safety risks associated with potential methane migration and seepage and pipeline ruptures would be minimal, in proportion to the increased number of project-related facilities.

Air Quality and Climate

Although the proposed Alternatives and non-project sources have the potential to emit carbon dioxide (CO_2) and methane, no measurable impacts to climate are anticipated from implementation of any of the proposed Alternatives. Potential impacts to air quality were analyzed as described below.

Issues, Impact Types, and Criteria

Fugitive dust and exhaust from construction activities, along with air pollutants emitted during operation (i.e., well operations, injection well and pipeline compressor engines, etc.), are potential causes of decreases in air quality. These issues are more likely to generate public concern where natural gas development activities occur near residential areas. The Crow Tribal Council and the federal land managers (FLMs) have expressed concerns regarding potential visibility and atmospheric deposition (acid rain) impacts within distant downwind PSD Class I and PSD Class II sensitive areas in Wyoming, Montana, southwestern North Dakota, western South Dakota, and northwestern Nebraska.

Air pollutant dispersion modeling was performed to quantify potential PM_{10} and SO_2 impacts during construction based on the individual pollutant's period of maximum potential emissions. The EPA CALPUFF dispersion model was used with meteorological data generated by the MM5 (mesoscale model) and CALMET models. These meteorology data were combined with air pollutant emission values to predict maximum potential concentrations in the vicinity of assumed well and compressor engine emission sources for comparison with applicable air quality standards and PSD Class II increments (Argonne 2002).

Construction emissions would occur during potential road and well pad construction, well drilling, and well completion testing. During well completion testing, natural gas may be flared and exhausted. Since the burned natural gas is "sweet" (does not contain sulfur compounds), no objectionable odors are likely to occur.

Maximum potential near-field particulate matter emissions from traffic on unpaved roads and during well pad construction were used to predict the maximum 24-hour and annual average PM_{10} concentrations. Maximum air pollutant emissions from each well would be temporary (i.e., occurring during a short construction period) and would occur in isolation, without significantly interacting with adjacent well locations. During construction, particulate matter emissions from well pad and resource road construction would be minimized by application of water. The control efficiency of the dust suppression was computed at 50 percent during construction. During production and maintenance, the Companies would not routinely employ dust abatement procedures on roads within the Project Area.

Air quality impacts from potential development were analyzed and reported in the following sections on Alternatives and Cumulative Impacts. This analysis was prepared solely under the requirements of NEPA to assess and disclose reasonably foreseeable impacts to the public and BLM and FS decision makers before a ROD is issued. The air quality impact assessment was based on the best available engineering data and assumptions, meteorology data, and dispersion modeling procedures, as well as professional and scientific judgment. However, where specific data or procedures were not available, reasonable assumptions were incorporated. For example, the Alternative 1 air quality impact assessment assumed that all CBM wells would go into production (no dry holes), then operate at full production levels (no shut-ins) for about 7 years, with an overall 20-year life of project (LOP). Potential direct project, indirect, and cumulative air quality impacts were analyzed to predict maximum potential near-field ambient air pollutant concentrations and potential hazardous air pollutant (HAP) impacts, as well as to determine maximum far-field ambient air pollutant concentrations, visibility, and atmospheric deposition (acid rain) impacts. The methodologies used to predict and interpret potential air quality impacts are described in the Air Quality appendix (Appendix F).

Air pollution impacts are limited by state, tribal and federal regulations, standards, and implementation plans established under the CAA and administered by the applicable air quality regulatory agencies (including the WDEQ – Air Quality Division [WDEQ-AQD] or the EPA). Although not applicable to the development alternatives, the Departments of Environmental Quality for Montana, South Dakota, and Nebraska have similar jurisdiction over potential air pollutant emission sources in their respective states, which can have a cumulative impact with WDEQ-AQD approved sources. Air quality regulations require proposed new, or modified existing air pollutant emission sources (including CBM compression facilities) to undergo a permitting review before their construction can begin. Therefore, the applicable air quality regulatory agencies have the primary authority and responsibility to review permit applications and to require emission permits, fees, and control devices, prior to construction and/or operation. The U.S. Congress (through the CAA Section 116) also authorized local, state, and tribal air quality regulatory agencies to establish air pollution control requirements more (but not less) stringent than federal requirements. Additional site-specific air quality analysis would be performed, and additional emission control measures (including a BACT analysis and determination) may be required by the applicable air quality regulatory agencies to ensure protection of air quality.

In addition, under both FLPMA and the CAA, BLM cannot authorize any activity which does not comply with all applicable local, state, tribal, and federal air quality laws, statues, regulations, standards, and implementation plans. An extensive air quality impact assessment technical support document was prepared to analyze potential impacts from the development alternatives, as well as other reasonably foreseeable emission sources, and is available for review (Argonne 2002).

The significance criteria for potential air quality impacts include state, tribal, and federally enforced legal requirements to ensure air pollutant concentrations will remain within specific allowable levels. These requirements include the NAAQS and WAAQS which set maximum limits for several air pollutants, and PSD increments which limit the incremental increase of certain air pollutants (including NO_2, PM_{10}, and SO_2) above legally defined baseline concentration levels. These legal limits were presented in Table 3–12.

Where legal limits have not been established, BLM uses the best available scientific information to identify thresholds of significant impacts. Thresholds have been identified for HAP exposure, incremental cancer risks, potential atmospheric deposition impacts to sensitive lakes, and a "just noticeable change" in potential visibility impacts.

Impacts Common to All Alternatives

Air quality impacts would occur during construction (due to potential surface disturbance by earth-moving equipment, vehicle traffic fugitive dust, well testing, as well as drilling rig and vehicle engine exhaust) and production (including non-CBM well production equipment, booster (field) and pipeline (sales) compression engine exhausts). The amount of air pollutant emissions during construction would be controlled by watering disturbed soils, and by air pollutant emission limitations imposed by applicable air quality regulatory agencies. Maximum construction impacts from fugitive dust (24 hour PM_{10}) are estimated to be 55 $\mu g/m^3$, about one third of the applicable WAAQS. Actual air quality impacts depend on the amount, duration, location, and emission characteristics of potential emissions sources, as well as meteorological conditions (wind speed and direction, precipitation, relative humidity, etc.).

The HAP impact analysis was based on a maximum assumed six-unit reciprocating compressor engine station, applicable for all proposed Alternatives, as de-

BEST COPY AVAILABLE

349

scribed in the Air Quality appendix (Appendix F). Since neither the WDEQ-AQD nor EPA have established HAP standards, predicted 8-hour HAP concentrations were compared to a range of 8-hour state maximum Acceptable Ambient Concentration Levels (EPA 1997a). Formaldehyde was the only HAP predicted to exceed even the lowest threshold level. The maximum predicted cumulative 8-hour formaldehyde impact was 11.9 $\mu g/m^3$, which is within the threshold range of 4.5 $\mu g/m^3$ (Pinnellas County Air Pollution Control Board, Florida) to 71 $\mu g/m^3$ (State of Nevada, Division of Environmental Protection, Air Quality Control). The maximum formaldehyde concentration was predicted to occur at 85 meters (less then 300 feet) adjacent to a compressor station; as the distance from the emission source increases, the predicted concentrations decrease rapidly.

Further analysis was conducted to determine the possible incremental cancer-risk over a 70 year lifetime for a most likely exposure (MLE) to residents, and to a maximally exposed individual (MEI), such as compressor station workers. These cancer risks were calculated based on the maximum predicted annual concentrations, EPA's unit risk factors for carcinogenic compounds (EPA 1997b), and an adjustment for time spent at home or on the job. This analysis assumed that residential exposure would be 20 years (well over the national nine year average duration a family lives at a residence) and worker exposure would be 20 years (the full LOP). In addition, it was assumed that family members would be exposed to the maximum formaldehyde concentrations 64 percent of the day, and to ¼ of this concentration for the remaining 36 percent of the day.

The resulting incremental cancer risks were calculated to be 1.6×10^{-6} (MLE) and 2.2×10^{-6} (MEI). Both of these values fall near the lower end of the 1 to 100×10^{-6} threshold. The MLE and MEI cancer risks would fall below this threshold at 310 and 460 meters away from the emission source, respectively. This distance would be even less for smaller compressor stations.

When reviewing the predicted near- and far-field impacts, it is important to understand that assumptions were made regarding potential resource development, emissions, meteorology, atmospheric transport and chemistry, and atmospheric deposition. For example, there is uncertainty regarding ultimate development (number of wells, equipment to be used, specific locations of wells, etc).

The following assumptions were used in the analysis:

- Total predicted short-term air pollutant impact concentrations were assumed to be the sum of the assumed background concentration, plus the predicted maximum cumulative modeled concentrations, which may occur under different meteorological conditions.
- Assumed background air pollution concentrations were assumed to occur throughout the 20-year LOP at all locations in the region, even though monitoring is primarily conducted in urban or industrial areas, rather than rural areas. The uniform background PM_{10} levels for each state are assumed to be representative of the background conditions for the entire modeled area of the PRB, based on monitoring data gathered throughout northeastern Wyoming and southeastern Montana.

350

- The maximum predicted air quality impacts occur only in the vicinity of the anticipated emission sources. Actual impacts would likely be less at distances beyond the predicted points of maximum impact.
- All emission sources were assumed to operate at their reasonably foreseeable maximum emission rates simultaneously throughout the LOP. Given the number of sources included in this analysis, the co-probability of such a scenario actually occurring over an entire year (or even 24-hours) is small.
- In developing the emissions inventory and model, there is uncertainty regarding ultimate development (i.e., number of wells, equipment to be used, specific locations, etc.) Most (90 percent) proposed CBM wells and 30 percent of conventional wells were assumed to be fully operational and remain operating (no shut ins) throughout the LOP.
- The total proposed booster (field) and pipeline (sales) compression engines were assumed to operate at their rated capacities continuously throughout the LOP (no phased increases or reductions). In reality, compression equipment would be added or removed incrementally as required by the well field operation, compressor engines would operate below full horsepower ratings, and it is unlikely all compressor stations would operate at maximum levels simultaneously.
- The HAP analyses assumed a 9,900 horsepower, six-unit, reciprocating compressor engine station would operate at full load and at maximum emission levels continuously throughout the LOP.
- The emissions inventory and model use peak years of construction and peak years of operations, which would not occur throughout the entire development region at the same time. However, it is possible that conditions close to this could occur in some isolated areas.
- The emissions inventory and model assumed a NO_x emission rate for compressor engines of 1.5 g/hp-hr in Montana and 1.0 g/hp-hr in Wyoming. Since BACT is decided on a case-by-case basis, actual emission rates could be decided to be less or more than this level by the Departments of Environmental Quality in Wyoming or Montana, and on Indian lands by EPA, for field and sales compressor engines. Actual NO_x emission rates may range from 0.7 to 2 g/hp-hr.
- There are no applicable local, state, tribal or federal acid deposition standards. In the absence of applicable standards, the acid deposition analysis assumed that a "limit of acceptable change@ is: a 10 percent change in acid neutralizing capacity (ANC) for lakes with a background ANC greater than 25 μeq/l; or a 1 μeq/l change in ANC for lakes with a background ANC less than 25 μeq/l, and would be a reasonably foreseeable significant adverse impact. Further, the atmospheric deposition impact analysis assumed no other ecosystem components would affect lake chemistry for a full year (assuming no chemical buffering due to interaction with vegetation or soil materials).
- The visibility impact analysis assumed that a 1.0 dv "just noticeable change" would be a reasonably foreseeable significant adverse impact, although there are no applicable local, state, tribal or federal regulatory visibility standards. However, some FLMs are using 0.5 dv as a screening threshold for significance.

- Mitigation measures are included in the emissions inventory and model that may not be achievable in all circumstances. However, actual mitigation decided by the developers and local and state authorities may be greater or less than those assumed in the analysis. For example, maintaining a construction road speed limit of 15 mph may be reasonable in a construction zone but difficult to enforce elsewhere. Full (100%) mitigation of fugitive dust from disturbed lands may not be achievable. Further, 50 percent reduction in fugitive emissions is assumed based on construction road wetting on the unimproved access road to the pad and at the pad, but this level of effectiveness is characterized as the maximum possible. Wetting was assumed for maintenance traffic, which is not likely to occur, but this is considered to be a small effect because of limited traffic.
- Induced or secondary growth related to increases in vehicle miles traveled (VMT) (believed to be on the order of 10 percent overall) is not included in the emissions inventory and model. Not all fugitive dust emissions (including county and other collector roads) have been included in the emissions inventory and model.
- Fugitive dust emissions from roads are treated as area sources rather than line sources in the model, which may thereby reduce or increase the predicted ambient concentrations at maximum concentration receptor points near the source, depending on the inputs to the model (meteorology, terrain, etc.) By not placing modeled receptors close to emission sources (e.g. wells and roads), the model may not capture higher ambient concentrations near these sources. A more refined, regulatory model may yield higher concentrations at locations near fugitive dust sources.
- For comparisons to the PSD Class I and II increments, the emissions inventory and model included only CBM and non-project sources. Other existing increment consuming sources such as Campbell County coal mines were not included in this comparison, as the air quality analysis does not represent a regulatory PSD increment consumption analysis. A regulatory PSD increment consumption analysis needs to identify and consider all PSD increment consuming sources to determine the level of PSD Class II increment consumption. Monitoring data in Wyoming has indicated an upward trend in PM concentrations in Campbell County since 1999, which coincides with CBM development but is also exacerbated by prolonged drought in the region.

Given these assumptions, the predicted impacts represent an estimate of potential air quality impacts.

It is important to note that before actual development could occur, the applicable air quality regulatory agencies (including the state, tribe or EPA) would review specific air pollutant emissions pre-construction permit applications that examine source-specific air quality impacts. As part of these permits (depending on source size), the air quality regulatory agencies could require additional air quality impacts analyses or mitigation measures. Thus, before development occurs, additional site-specific air quality analyses would be performed to ensure protection of air quality.

Impacts from Temporary Generation

The exact number of temporary natural gas and diesel generators for compressor stations cannot be predicted, but at any one time there may be as many as 400 portable diesel generators and 70 portable gas generators operating. Typical emission factors (in grams per horsepower per hour (g/hp-hr)) for these generators are shown in Table 4–87. Table 4–88 shows the potential ground-level concentrations resulting from operation of these temporary generators.

Table 4–87 Emission Factors for Temporary Generation

Pollutant	Emission Factor Range (g/hp-hr)
Carbon monoxide	0.3 – 2.0
Oxides of nitrogen	0.7 – 1.5
$PM_{2.5}$	0.03 – 0.07
Sulfur dioxide	0.002
Volatile organic compounds	0.5 – 1.0
Formaldehyde	0.05 – 0.2

Alternative 1

Potential direct project air quality impacts would not violate any local, state, tribal, or federal air quality standards under Alternative 1. Based on extensive air quality modeling of potential direct project air quality impacts (Argonne 2002), localized short-term increases in CO, NO_x, PM_{10}, and SO_2 concentrations would occur, but all maximum concentrations are expected to be below applicable NAAQS and WAAQS. All maximum near-field direct project NO_2, PM_{10} and SO_2 concentrations are expected to be below applicable PSD Class II increments (Table 4–89), and all maximum far-field direct project concentrations are expected to be below applicable PSD Class I increments (see Appendix F).

Table 4–88 Near-Field Concentrations from a Single Temporary Generator

Pollutant	Averaging Time	Concentration Range ($\mu g/m^3$)	WAAQS ($\mu g/m^3$)
Carbon monoxide	1-hour	55.3 – 403.1	40,000
	8-hour	33.2 – 242.9	10,000
Nitrogen dioxide	Annual	1.9 – 7.5	100
$PM_{2.5}$	24-hour	1.5 – 5.3	65
	Annual	0.1 – 0.4	15
Sulfur dioxide	3-hour	0.2 – 0.4	1,300
	24-hour	0.09 – 0.3	260
	Annual	0.007 – 0.013	60

Although potential direct project impacts to even the most sensitive far-field lakes would not be significant, a "just noticeable change" in visibility was predicted to occur at eleven mandatory federal Class I areas, ranging up to five days at the Washakie Wilderness Area. The maximum potential direct project visibility impacts were predicted to occur on 20 days per year on the Crow Indian Reservation. A detailed description of the air quality impact analysis is presented in the Air Quality appendix (Appendix F).

Table 4–89 Maximum Potential Near-Field Impacts from Wyoming Alternative 1 (with Montana Alternative E)

Pollutant	Averaging Time	Project ($\mu g/m^3$)	Non-Project ($\mu g/m^3$)^1	Cumulative ($\mu g/m^3$)	PSD Class II ($\mu g/m^3$)	Background ($\mu g/m^3$)	Total ($\mu g/m^3$)^2	WAAQS ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
NO_2	Annual	8	3	10	25	17	28	100	100
SO_2	Annual	<1	<1	1	20	3	4	60	80
	24 hour	2	2	3	91	8	11	260	365
	3 hour	3	5	5	512	8	13	1,300	1,300
PM_{10}	Annual	3	1	4	17	17	21	50	50
	24 hour	20	9	31	30	42	73	150	150
$PM_{2.5}$	Annual	2	1	2		8	10	15	15
	24 hour	16	9	24		19	43	65	65
CO	8 hour	156	124	156		1,500	1,656	10,000	10,000
	1 hour	223	142	224		3,500	3,724	40,000	40,000

Notes:
1. Non-Project sources include CBM sources in Montana.
2. The contributions from each source represent maxima and do not necessarily occur at the same location. Therefore, the total concentrations will not always equal the sum of the monitored background, Project and Non-Project concentrations.

Alternative 2A

Potential direct project air quality impacts would not violate any local, state, tribal, or federal air quality standards under Alternative 2A. Based on extensive air quality modeling of potential direct project air quality impacts (Argonne 2002), localized short-term increases in CO, NO_x, PM_{10}, and SO_2 concentrations would occur, but all maximum concentrations are expected to be below applicable NAAQS and WAAQS. All maximum near-field direct project NO_2, PM_{10} and SO_2 concentrations are expected to be below applicable PSD Class II increments (Table 4–90), and all maximum far-field direct project concentrations are expected to be below applicable PSD Class I increments (see Appendix F).

Although potential direct project impacts to even the most sensitive far-field lakes would not be significant, a "just noticeable change" in visibility was predicted to occur at 10 mandatory federal Class I areas, ranging from one day at two areas up to four days at both the Bridger and Washakie Wilderness Areas. The maximum potential direct project visibility impacts were predicted to occur on 16 days per year within both the tribal designated PSD Class I Northern Cheyenne and the PSD Class II Crow Indian Reservations. A detailed description of the air quality impact analysis is presented in the Air Quality appendix (Appendix F).

354

Table 4–90 Maximum Potential Near-Field Impacts from Wyoming Alternative 2A (with Montana Alternative E)

Pollutant	Averaging Time	Project ($\mu g/m^3$)	Non-Project ($\mu g/m^3$)[1]	Cumulative ($\mu g/m^3$)	PSD Class II ($\mu g/m^3$)	Background ($\mu g/m^3$)	Total ($\mu g/m^3$)[2]	WAAQS ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
NO_2	Annual	7	3	10	25	17	27	100	100
SO_2	Annual	<1	<1	1	20	3	4	60	80
	24 hour	2	2	3	91	8	11	260	365
	3 hour	3	5	5	512	8	13	1,300	1,300
PM_{10}	Annual	3	1	4	17	17	21	50	50
	24 hour	17	9	28	30	42	70	150	150
$PM_{2.5}$	Annual	1	1	2		8	10	15	15
	24 hour	13	9	12		19	40	65	65
CO	8 hour	93	124	132		1,500	1,632	10,000	10,000
	1 hour	158	142	197		3,500	3,697	40,000	40,000

Notes:

1. Non-Project sources include CBM sources in Montana.
2. The contributions from each source represent maxima and do not necessarily occur at the same location. Therefore, the total concentrations will not always equal the sum of the monitored background, Project and Non-Project concentrations.

Alternative 2B

Potential direct project air quality impacts would not violate any local, state, tribal, or federal air quality standards under Alternative 2B. Based on extensive air quality modeling of potential direct project air quality impacts (Argonne 2002), localized short-term increases in CO, NO_x, PM_{10}, and SO_2 concentrations would occur, but all maximum concentrations are expected to be below applicable NAAQS and WAAQS. All maximum near-field direct project NO_2, PM_{10} and SO_2 concentrations are expected to be below applicable PSD Class II increments (Table 4–91), and all maximum far-field direct project concentrations are expected to be below applicable PSD Class I increments (see Appendix F).

Although potential direct project impacts to even the most sensitive far-field lakes would not be significant, a "just noticeable change" in visibility was predicted to occur at nine mandatory federal Class I areas, ranging from one day at three areas up to four days at the Washakie Wilderness Area. The maximum potential direct project visibility impacts were predicted to occur on 14 days per year within the tribal designated PSD Class I Northern Cheyenne and the PSD Class II Crow Indian Reservations. A detailed description of the air quality impact analysis is presented in the Air Quality appendix (Appendix F).

Table 4–91 Maximum Potential Near-Field Impacts from Wyoming Alternative 2B (with Montana Alternative E)

Pollutant	Averaging Time	Project ($\mu g/m^3$)	Non-Project ($\mu g/m^3$)[1]	Cumulative ($\mu g/m^3$)	PSD Class II ($\mu g/m^3$)	Background ($\mu g/m^3$)	Total ($\mu g/m^3$)[2]	WAAQS ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
NO_2	Annual	6	3	9	25	17	26	100	100
SO_2	Annual	<1	<1	1	20	3	4	60	80
	24 hour	2	2	3	91	8	11	260	365
	3 hour	3	45	5	512	8	13	1300	1300
PM_{10}	Annual	3	1	4	17	17	20.72	50	50
	24 hour	15	9	25	30	42	67.45	150	150
$PM_{2.5}$	Annual	1	1	2		8	9.97	15	15
	24 hour	11	9	19		19	38.03	65	65
CO	8 hour	77	124	124		1,500	1,624	10,000	10,000
	1 hour	157	142	170		3,500	3,670	40,000	40,000

Notes:

1. Non-Project sources include CBM sources in Montana.
2. The contributions from each source represent maxima and do not necessarily occur at the same location. Therefore, the total concentrations will not always equal the sum of the monitored background, Project and Non-Project concentrations.

BEST COPY AVAILABLE

355

Alternative 3

Potential direct project air quality impacts would not violate any local, state, tribal, or federal air quality standards under Alternative 3. Based on extensive air quality modeling of potential direct project air quality impacts (Argonne 2002), localized short-term increases in CO, NO_x, PM_{10}, and SO_2 concentrations would occur, but all maximum concentrations are expected to be below applicable NAAQS and WAAQS. All maximum near-field direct project NO_2, PM_{10} and SO_2 concentrations are expected to be below applicable PSD Class II increments (Table 4–92), and all maximum far-field concentrations are expected to be below applicable PSD Class I increments (see Appendix F).

Although potential direct project impacts to even the most sensitive far-field lakes would not be significant, a "just noticeable change" in visibility was predicted to occur one day per year at the mandatory federal Class I Bridger, Fitzpatrick and Washakie Wilderness Areas. The maximum potential direct project visibility impacts were predicted to occur on 10 days per year on the Crow Indian Reservation. A detailed description of the air quality impact analysis is presented in the Air Quality appendix (Appendix F).

Table 4–92 Maximum Potential Near-Field Impacts from Wyoming Alternative 3 (with Montana Alternative E)

Pollutant	Averaging Time	Averaging Time	Project ($\mu g/m^3$)	Non-Project ($\mu g/m^3$)[1]	Cumulative ($\mu g/m^3$)	PSD Class II ($\mu g/m^3$)	Background ($\mu g/m^3$)	Total ($\mu g/m^3$)[2]	WAAQS ($\mu g/m^3$)
NO_2	Annual	3	3	6	25	17	23	100	100
SO_2	Annual	<1	<1	<1	20	3	3	60	80
	24 hour	1	1.75	2	91	8	10	260	365
	3 hour	1	4.53	5	512	8	13	1,300	1,300
PM_{10}	Annual	1	0.86	2	17	17	19	50	50
	24 hour	7	9.34	16	30	42	58	150	150
$PM_{2.5}$	Annual	<1	0.7	1		8	9	15	15
	24 hour	6	8.55	13		19	32	65	65
CO	8 hour	183	123.95	183		1,500	1,683	10,000	10,000
	1 hour	261	141.72	261		3,500	3,761	40,000	40,000

Notes:

1. Non-Project sources include CBM sources in Montana.
2. The contributions from each source represent maxima and do not necessarily occur at the same location. Therefore, the total concentrations will not always equal the sum of the monitored background, Project and Non-Project concentrations.

Cumulative Impacts

Based on a separate assessment predicting potential far-field cumulative air quality impacts (Argonne 2002), the EPA CALMET/CALPUFF dispersion model system was used to predict maximum potential air quality impacts at downwind mandatory federal PSD Class I areas, and other sensitive receptors, to: 1) determine if the WAAQS, NAAQS or PSD Class I increments might be exceeded; 2) calculate potential nitrate and sulfate atmospheric deposition (and their related impacts) in sensitive lakes; and 3) predict potential impacts to visibility (regional haze).

Meteorological information was assembled to characterize atmospheric transport and dispersion from several data sources, including: 1) 4 km gridded wind field values derived from the MM5 (mesoscale model) with continuous four-dimensional data assimilation; and 2) hourly surface observations (wind speed,

256

wind direction, temperature, cloud cover, ceiling height, surface pressure, relative humidity, and precipitation).

For each Alternative, potential air pollutant project sources were combined with non-project sources to determine the total potential cumulative air quality impacts. This included potential cumulative sources from the Montana Statewide Draft Oil and Gas EIS sources. The range of potential cumulative impacts correspond to including either the Montana Alternative A (low) or the Montana Alternative B/C/E (high) emission sources.

As described above, potential CO and NO_x emissions from reasonably foreseeable booster (field) and pipeline (sales) compressor stations, as well as $PM_{2.5}$, PM_{10}, and SO_2 emissions from construction equipment, were analyzed to predict potential maximum near-field PSD Class II impacts, as well as potential far-field impacts at 29 mandatory federal PSD Class I and other sensitive areas located in Wyoming, Montana, North and South Dakota, and Nebraska (Argonne 2002). Total concentrations are expected to be in compliance with applicable WAAQS and NAAQS (see Appendix F). Table 4–93 presents the maximum predicted air pollutant concentrations at specified PSD Class I areas.

Table 4–93 Maximum Predicted PSD Class I Area Cumulative Far-Field Impacts (in µg/m3) Alternative 1 (Proposed Action)

Pollutant	Averaging Period	Class I Area	Maximum Modeled Conc. (Cumulative)	PSD Class I Increment
Nitrogen dioxide	Annual	Northern Cheyenne Reservation	4.2	2.5
PM_{10}	24-hour	Northern Cheyenne Reservation	12.8	8
	Annual	Northern Cheyenne Reservation	1.7	4
Sulfur dioxide	3-hour	Northern Cheyenne Reservation	5.1	25
	24-hour	Absaroka-Beartooth Wilderness	2.4	5
	Annual	Northern Cheyenne Reservation	0.3	2

Source: Argonne 2002

Under all four Alternatives (1, 2A, 2B, and 3), potential non-project and cumulative annual NO2 concentrations (ranging from 4.1 to 4.2 µg/m^3) were predicted to be above the PSD Class I increment (2.5 µg/m^3) within the Northern Cheyenne Reservation. Under all four alternatives, potential project and cumulative 24-hour PM_{10} concentrations (ranging from 10.7 to 12.8 µg/m^3) were above the PSD Class I increment (8 µg/m^3) within the Northern Cheyenne Reservation. Under Alternatives 1, 2A, and 2B, cumulative 24-hour PM_{10} concentrations (ranging from 8.5 to 9.2 µg/m^3) were also predicted to be above the PSD Class I increment (8 µg/m^3) within the Washakie Wilderness Area. As described in the Air Quality Appendix (Appendix F), other PSD Class I areas had predicted far-field impacts below applicable increments. All PSD Class II areas had predicted far-field impacts below applicable PSD increments. This NEPA analysis compares potential

357

air quality impacts from the proposed Alternatives to applicable ambient air quality standards and PSD increments, but comparisons to the PSD Class I and II increments are intended to evaluate a threshold of concern for potential impacts, and do not represent a regulatory PSD Increment Consumption Analysis. Even though most of the development activities would occur within areas designated PSD Class II, the potential impacts on regional Class I areas are to be evaluated. For a new source review air quality permit application for a major source, the applicable air quality regulatory agencies may require a regulatory PSD increment analysis. More stringent emission controls beyond BACT may be stipulated in the air quality permit if impacts are predicted to be greater than the PSD Class I or II increments.

Several lakes within four FS-designated wilderness areas were identified as being sensitive to atmospheric deposition and for which the most recent and complete data have been collected. The FS has also identified the following Limit of Acceptable Change regarding potential changes in lake chemistry: no more than a 10 percent change in ANC for those water bodies where the existing ANC is at or above 25 µeq/L; and no more than a one µeq/L change for those extremely sensitive water bodies where the existing ANC is below 25 µeq/L.

Based on a Rocky Mountain Region FS screening method (FS 2000), Table 4–94 demonstrates that potential impacts to most sensitive lakes would be below applicable significance thresholds. However, under all four Alternatives (1, 2A, 2B, and 3), potential non-project ANC impacts (1.3 µeq/L)were predicted to exceed the 1.0 µeq/L impact threshold at the very sensitive Upper Frozen Lake within the PSD Class I Bridger Wilderness Area. Cumulative ANC impacts ranged from 1.6 to 1.8 µeq/L. Nearly 12 to 27 percent of these impacts are due to direct contributions from Alternatives 1, 2A, 2B, and 3 alone. In addition, under Alternatives 1 and 2A cumulative ANC impacts (up to 10.7 percent) were predicted to exceed the 10 percent impact threshold at the Florence Lake within the PSD Class II Cloud Peak Wilderness Area. Nearly 29 and 27 percent of these impacts are due to direct contributions from Alternatives 1 and 2A, respectively. Potential impacts at all other sensitive lakes (and under all Alternatives) were below the ANC threshold levels. No sensitive lakes were identified by either the U.S. Department of the Interior (USDI) National Park Service (NPS) or USFWS.

Since the development of the project and non-project air pollutant emission sources constitute many small sources spread out over a very large area, discrete visible plumes are not likely to affect the mandatory federal PSD Class I areas, but the potential for cumulative visibility impacts (increased regional haze) is a concern. Regional haze degradation is caused by fine particles and gases scattering and absorbing light. Potential changes to regional haze are calculated in terms of a perceptible "just noticeable change" (1.0 dv) in visibility when compared to background conditions.

Table 4–94 Predicted Total Cumulative Change in Acid Neutralizing Capacity at Sensitive Area Lakes (percent change)

Wilderness Area	Lake	Background ANC (µeq/L)	Area (hectares)	Change (percent)	Thresholds (percent)
Bridger	Black Joe	69	890	2.2 to 2.1	10
	Deep	61	205	2.5 to 3.0	10
	Hobbs	68	293	1.3 to 1.5	10
	Upper Frozen	5.8[a]	65	1.6 to 1.9[b]	1[b]
Fitzpatrick	Ross	61.4	4,455	1.8 to 2.1	10
Absaroka-Beartooth	Stepping Stone	27	26	2.3 to 2.5	10
	Twin Island	36	45	1.6 to 1.8	10
Cloud Peak	Emerald	55.3	293	5.0 to 6.0	10
	Florence	32.7	417	8.9 to 10.7	10
Popo Agie	Lower Saddlebag	55.5	155	3.2 to 3.8	10

Notes:

a. The background concentration is based on only six samples taken on four days between 1997 and 2001.

b. Since the background ANC value is less than 25 µeq/L, the potential ANC change is expressed in µeq/L, and the applicable threshold is one µeq/L

Source: Argonne 2002

A 1.0 dv change is considered a small but noticeable change in haziness as described in the Preamble to the EPA Regional Haze Regulations (Federal Register, Vol. 64 No. 126, dated July 1, 1999). A 1.0 dv change is defined as about a 10 percent change in the extinction coefficient (corresponding to a 2 to 5 percent change in contrast, for a black target against a uniform sky, at the most optically sensitive distance from an observer), which is a small but noticeable change in haziness under most circumstances when viewing scenes within mandatory federal Class I areas.

It should be noted that a 1.0 dv change is not a "just noticeable change" in all cases for all scenes. Visibility changes less than 1.0 dv are likely to be perceptible in some cases, especially where the scene being viewed is highly sensitive to small amounts of pollution, such as due to preferential forward light scattering. Under other view-specific conditions, such as where the sight path to a scenic feature is less than the maximum visual range, a change greater than 1.0 dv might be required to be a "just noticeable change."

However, this NEPA analysis is not designed to predict specific visibility impacts for specific views in specific mandatory federal Class I areas based on specific project designs, but to characterize reasonably foreseeable visibility conditions that are representative of a fairly broad geographic region, based on reasonable emission source assumptions. This approach is consistent with both the nature of regional haze and the requirements of NEPA. At the time of a preconstruction air quality PSD permit application, the applicable air quality regulatory agency may require a much more detailed visibility impact analysis. Factors such as the magnitude of dv change, frequency, time of the year, and the meteorological conditions during times when predicted visibility impacts are above the 1.0 dv threshold (as well as the modeling analyses assumptions) should all be

357

considered when assessing the significance of predicted impacts.

The FS, NPS, and USFWS have published their Final FLAG Phase I Report (*Federal Register*, Vol. 66 No. 2, dated January 3, 2001), providing "a consistent and predictable process for assessing the impacts of new and existing sources on AQRVs" including visibility. For example, the FLAG report states "A cumulative effects analysis of new growth (defined as all PSD increment-consuming sources) on visibility impairment should be performed," and further, "If the visibility impairment from the proposed action, in combination with cumulative new source growth, is less than a change in extinction of 10 percent [1.0 dv] for all time periods, the FLMs will not likely object to the proposed action." Although the FLAG procedures were primarily designed to provide analysis guidance to PSD permit applicants, the following analysis uses the Final FLAG Phase I Report procedures for this NEPA analysis.

Based on multiple iterations of the non-steady state CALPUFF dispersion modeling system, including the CALMET meteorological model, for four different development alternatives, potential cumulative visibility impacts estimated by the seasonal FLAG screening method exceeded the impact thresholds (including the use of FLAG and WDEQ-AQD provided background extinction values) at all 29 sensitive areas analyzed. Therefore, potential maximum visibility impacts were estimated using the daily FLAG refined method (based on hourly optical extinction and relative humidity values measured at two IMPROVE monitoring locations) for each Class I and Class II sensitive area. Although the potential modeled impacts for each sensitive area were based on 1996 MM5 regional meteorology, these values were compared to hourly optical extinction and relative humidity data collected at two locations in the Project Area between 1989 and 1999.

For example, since the 1.0 dv threshold was predicted to be reached within the mandatory federal PSD Class I Washakie Wilderness Area based on the seasonal FLAG screening methodology, the maximum modeled cumulative impacts at that area were also compared to representative hourly optical and relative humidity values measured at Bridger Wilderness Area between 1989 and 1999 using the daily FLAG refined method (Table 4–95). The range of impacts was then summarized as the maximum annual average number of days predicted to equal or exceed a 1.0 dv "just noticeable change" (Table 4–96). Table 4–97 shows predicted visibility impacts in Class I Areas using the daily FLAG refined method.

The prediction of potential visibility impacts based on the daily FLAG refined methodology using measured optical extinction conditions is intended to disclose potential air quality impacts of the Proposed Action and Alternatives on the Affected Environment to the public and decision maker before an action is taken. It is not intended to be an air quality regulatory analysis. Such analysis would be conducted by the applicable air quality regulatory agencies.

360

Table 4–95 **Predicted Visibility Impacts in the Mandatory Federal PSD Class I Washakie Wilderness Area from Direct Alternative Sources - Daily FLAG Refined Method (Average Number of Days per Year Predicted to Equal or Exceed a 1.0 dv "Just Noticeable Change")**

Alternative	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	4	2	7	6	4	7	4	6	7	2	6
2A	2	2	6	5	4	6	4	5	5	1	4
2B	1	2	6	5	3	6	4	4	5	1	3
3	1	0	4	3	1	1	2	2	2	0	0

Note:

Potential cumulative visibility impacts were predicted using daily background optical and relative humidity conditions for each of the years listed above.

Source: Argonne 2002

Table 4–96 **Predicted Visibility Impacts in Class I Areas – Daily FLAG Refined Method (Average Number of Days per Year Predicted to Equal or Exceed a 1.0 dv "Just Noticeable Change")**

Class I Area	Alt 1	Alt 2A	Alt 2B	Alt 3	Non-Project Sources	Cum Sources
Badlands Wilderness Area[1]	3	3	1	0	13 to 17	18 to 28
Bridger Wilderness Area	4	4	3	1	7 to 9	8 to 12
Fitzpatrick Wilderness Area	4	3	3	1	6 to 9	8 to 12
Gates of the Mtns Wilderness Area	0	0	0	0	3 to 4	3 to 4
Grand Teton National Park	1	1	0	0	3 to 5	4 to 8
North Absaroka Wilderness Area	4	3	2	0	9 to 13	11 to 15
Red Rock Lakes Wilderness Area	0	0	0	0	0 to 1	0 to 3
Scapegoat Wilderness Area	0	0	0	0	2 to 2	2 to 3
Teton Wilderness Area	3	3	2	0	6 to 9	7 to 11
Theodore Roosevelt NMP[2] (North Unit)	0	0	0	0	1 to 1	1 to 3
Theodore Roosevelt NMP[2] (South Unit)	1	0	0	0	1 to 3	2 to 7
U.L. Bend Wilderness Area	1	1	1	0	4 to 5	5 to 8
Washakie Wilderness Area	5	4	4	1	10 to 14	12 to 18
Wind Cave National Park	4	3	2	0	17 to 21	22 to 28
Yellowstone National Park	3	2	1	0	8 to 11	9 to 13
Northern Cheyenne Reservation[3]	17	16	14	7	27 to 82	33 to 92

Notes:

1. The U.S. Congress designated the Wilderness Area portion of Badlands National Park as a mandatory federal PSD Class I area. The remainder of Badlands National Park is a PSD Class II area.
2. NMP - National Memorial Park.
3. Although the Northern Cheyenne Reservation is a tribal designated PSD Class I Area, it is not a mandatory federal PSD Class I area subject to EPA's Regional Haze Regulations.

Non-Project Sources – The impact of all air pollutant emission sources not included in Alt 1, Alt 2A, Alt 2B or Alt 3, including the Montana "Powder River Basin Oil and Gas Project" DEIS sources. The range of potential annual average days above a 1.0 dv "just noticeable change" in visibility corresponds to including Montana Alternative A (low) to Montana Alternative B/C/E (high).

Cum Sources – The impact of all cumulative air pollutant emission sources combined, including the Alt 1, Alt 2A, Alt 2B, Alt 3, and Non-Project Sources, including the Montana "Powder River Basin Oil and Gas Project" DEIS sources. The range of potential annual average days above a 1.0 dv "just noticeable change" in visibility corresponds to: includingNon-Project, Wyoming Alternative 3 and Montana Alternative A sources (low); up to includingProject, Wyoming Alternative 1 and Montana Alternative B/C/E sources (high).

Source: Argonne 2002

Table 4–97 Predicted Visibility Impacts in Class I Areas – Daily FLAG Refined Method (Maximum cumulative deciview change)

	Alternative			
Class I area	1	2A	2B	3
Badlands Wilderness Area	10.91	10.67	10.43	9.46
Bridger Wilderness Area	13.28	12.67	12.21	11.15
Fitzpatrick Wilderness Area	16.57	15.83	15.21	14.01
Gates of the Mtns Wilderness Area	14.99	14.61	14.22	13.17
Grand Teton National Park	6.95	6.67	6.44	5.8
North Absaroka Wilderness Area	14.89	14.12	13.51	12.21
Red Rock Lakes Wilderness Area	2.85	2.75	2.67	2.37
Scapegoat Wilderness Area	9.89	9.58	9.35	8.55
Teton Wilderness Area	14.59	13.97	13.46	12.38
Theodore Roosevelt NMP[2] (North Unit)	3.65	3.46	3.29	2.75
Theodore Roosevelt NMP[2] (South Unit)	4.62	4.37	4.14	3.51
U.L. Bend Wilderness Area	29.05	27.97	26.97	24.01
Washakie Wilderness Area	24.79	23.82	22.96	21.48
Wind Cave National Park	9.05	8.81	8.59	8.06
Yellowstone National Park	12.79	12.19	11.59	10.25
Northern Cheyenne Reservation[3]	54.75	52.8	50.71	45.02

It is important to note that before actual development could occur, the applicable air quality regulatory agencies (including the state, tribe or EPA) would review specific air pollutant emissions pre-construction permit applications that examine source-specific air quality impacts. As part of these permits (depending on source size), the air quality regulatory agencies could require additional air quality impacts analyses or mitigation measures. Thus, before development occurs, additional site-specific air quality analyses would be performed to ensure protection of air quality. For further mitigation information see the air quality appendix.

Mitigation

Through the analysis, several potential mitigation measures were identified to avoid, reduce, or minimize adverse effects to various resources. The BLM and FS can require these measures for leases with federal land surface and federal minerals and non-federal land surface and federal minerals (split estate). These are new measures in addition to mitigation measures that have been carried forward from the Wyodak FEIS and ROD and the Wyodak Drainage EA and Decision Notice and are included in Appendix C. and Appendix M. Any of the following mitigation measures may be adopted by the decision makers. Those measures adopted by the decision makers will be disclosed in the ROD. Those adopted will be added or will replace or revise the mitigation measures already identified in the programmatic mitigation plan.

Groundwater

1. Concerns exist about the interaction between reservoirs and shallow groundwater. At impoundment locations, it may be necessary to conduct investigations at representative sites around the basin to quantify impacts of water infiltration and lateral movement. Shallow groundwater wells

would be installed and regularly sampled in areas where it has been determined during pre-construction that class 1 groundwater may be affected by infiltration or potential for lateral movement exists.

Surface Water

2. Channel crossings by pipelines would be constructed so that the pipe is buried at least four feet below the channel bottom.
3. Channel crossings by road and pipelines would be constructed perpendicular to flow. Culverts would be installed at appropriate locations for streams and channels crossed by roads as specified in the BLM Manual 9112-Bridges and Major Culverts and Manual 9113-Roads. Streams would be crossed perpendicular to flow, where possible, and all stream crossing structures would be designed to carry the 25-year discharge event or other capacities as directed by the BLM.
4. Disturbed channel beds would be reshaped to their approximate original configuration and stabilized by appropriate means.
5. Areas where natural springs are present, operators would be required to identify, inventory, and monitor these springs as part of their water management plan development.
6. Concerns regarding the quality of the discharged CBM water for irrigation use may require operators to increase the amount of storage of CBM water during the irrigation months and allow more surface discharge during the non-irrigation months.
7. Concerns regarding the potential for discharges of CBM water to reach the main stems would be minimized by locating discharge outfalls higher in ephemeral and intermittent drainages or near the drainage divide.

Soils

8. Land application of produced water has the potential to produce negative, long term impacts to soil physical and chemical properties if not properly managed. Proposals to land apply CBM produced water on federal projects must include the following information as part of the exploratory and/or permanent water management plans:

   Site characterization: The site characterization must include field investigations of soils and vegetation. The site would be described in detail, and soil samples would be collected and analyzed to determine important soil chemical and physical properties. Site descriptions would include maps, vegetation descriptions, soils descriptions, laboratory analysis and location of proposed application sites. Photo documentation of the site would be included. Laboratory analysis of produced water would also be included with the site characterization study.

   Project description: The project description must include the proposed method(s) of water application, application rates and schedules and physical layout of application areas. Complete maps of the application infrastructure would be included. Details on any soil or water amendments that would be used or physical soil manipulations that would be planned. Project descriptions would demonstrate that land application is feasible given the results of the site characterization.

Monitoring Plan: Periodic monitoring of soils and vegetation would be required of the operator to assure that negative impacts are not occurring, or are being remediated. Monitoring must include soil sampling and laboratory analysis.

Winter operations: Detail practices that would be used to prevent the buildup of ice on the soil surface during sub freezing temperatures.

Mitigation Plan: A plan must be developed which outlines mitigation measures that would be implemented by the operator in the event negative soils or vegetation impacts are detected during routine monitoring. Potential mitigation measures might include, but not be limited to, soil or water amendments, physical manipulation or vegetative treatments.

These criteria are general in nature, and must be adjusted to site-specific conditions. Detailed soil sampling criteria have not yet been developed, so project proposals will be evaluated on a case-by-case basis during the interim. More specific guidance/requirements may be forthcoming as the result on ongoing research and coordination.

9. The Companies would segregate soil horizons during excavation of all project facilities and avoid mixing of soil horizons during stockpiling and redistribution of soils.
10. The Companies would test sediments deposited in impoundments before reclaiming the impoundments. Tests would include the standard suite of cations, ions, and nutrients that would be monitored in surface water testing and any trace metals found in the CBM discharges at concentrations exceeding detectable limits.

Cultural Resources

11. The Companies would conduct CBM development in and around the Crazy Woman Battlefield in a way that preserves the eligibility of the site for nomination to the National Register of Historic Places. Approvals of APDs and PODs would require prior coordination with the SHPO and BLM's archaeologists.
12. For development within 0.5 mile either side of the Bozeman Trail, companies would conduct evaluation of segments to determine their eligibility to the National Register of Historic Places. Mitigation of adverse impacts to segments of the trail that contributes to its eligibility for the NRHP would be determined on a case-by-case basis.
13. Should human remains be unearthed during construction, procedures outlined in the human remains plan (Appendix L) would be followed.
14. At a minimum, all areas of proposed ground disturbing activity would be intensively inventoried for cultural resources in conformance with minimal BLM Class III survey standards at the APD, POD or Sundry Notice phase of each proposed Federal undertaking. For CBM well fields or

PODs, a block survey of the entire project area early in the planning phase is highly recommended by the BLM and is required by the FS. All sites within the proposed project area must be evaluated for eligibility to the NRHP.

Specific plans for avoidance and protection or minimization of adverse direct or indirect effects would be recommended for any historic properties within the areas of potential effect of proposed project activities. Prior to implementation, these plans must be approved by the BLM or FS, as appropriate, SHPO, and, if applicable, by the private surface owner. Such plans might include, but are not limited to the following constraints, stipulations, or actions:

- Relocation, redesign or constraint of project facilities and infrastructure to avoid or minimize earth disturbance within historic properties or contributing portions of historic properties, or to avoid or minimize indirect effects or intrusions caused by vibration, dust, exhaust, or noise. This may include barricading or fencing of sensitive areas and buffer zones.
- Relocation, redesign, or constraint of project facilities and infrastructure to avoid or minimize visual intrusion on a sensitive historic, traditional, or religious setting. This might include low profile facilities, non-intrusive colors, landscaping, berms, screening with vegetation, or other measures to minimize visual impact.
- Stabilization of sediments, bedrock, or structures that could be destabilized, or could deteriorate, as a result of nearby project activities and identification of an appropriate buffer zone.
- Restriction or prevention of access to sensitive areas.
- Rehabilitation of buildings or structures, or protective screening of art work to minimize deterioration.
- Detailed documentation, possibly including archival photodocumentation, of contributing structures, landscape features, or aspects of historic setting that cannot feasibly be avoided. In some cases it may be feasible to restore some of these contributing features after construction has been completed.
- Detailed recordation or data recovery of the essential contributing elements of a historic property that cannot be avoided or protected. Recordation may include archival, documentary, and contextual research related to the historic property in addition to site documentation. Data recovery is the systematic recovery of data important in history or prehistory for which the property is considered eligible. Data recovery for prehistoric or historic archaeological sites typically entails excavation of buried materials and detailed documentation of stratigraphic context.

Vegetation

15. Companies would be required to submit an integrated pest management plan (Appendix N) as a component of the APD and POD approval process. The components of the integrated pest management plans are out-

lined in the BFO CBM APD and POD Preparation Guide. Companies would need to contact County Weed and Pest offices to ascertain information about weeds in the area of their APD or POD. Mitigation would be determined on a site-specific basis and may include such measures as spraying herbicides before entering areas and washing vehicles before leaving infested areas.

16. Any mulch and seed used for reclamation needs to be certified weed free and current year's tested.
17. Weed educational material would be reviewed with operators during preconstruction on-site meetings with operators, subcontractors, and landowners and would also be attached to approved APDs and PODs.

Wetland/Riparian

18. To protect the biological and hydrologic feastures of riparian areas, woody draws, wetlands, and floodplains, all well pads, compressors, and other non-linear facilities would be located outside of these areas.
19. The Companies would inventory and map riparian areas that cannot tolerate year-round inundation of root zones in the area of each APD or POD. Facilities to handle the water discharged from CBM wells would be developed to avoid inundation of these riparian areas.
20. Crossings of wetland/riparian areas by linear features, such as pipelines, roads, and power lines would be avoided to the extent practicable. Where crossings cannot be avoided, impacts would be minimized through use of the following measures:
    - Site-specific mitigation plans would be developed during the APD, POD, or Sundry Notice approval process for all proposed disturbance to wetland/riparian areas.
    - Crossings would be constructed perpendicular to wetland/riparian areas, where practical.
    - For power lines, the minimum number of poles necessary to cross the area would be used.
    - Wetland areas would be disturbed only during dry conditions (that is, during late summer or fall), or when the ground is frozen during the winter.
    - No waste material would be deposited below high water lines in riparian areas, flood plains, or in natural drainage ways.
    - The lower edge of soil or other material stockpiles would be located outside the active floodplain.
    - Drilling mud pits would be located outside of riparian areas, wetlands, and floodplains, where practical.
    - Disturbed channels would be re-shaped to their original configuration and properly stabilized.
    - Reclamation of disturbed wetland/riparian areas would begin immediately after project activities are complete.

Wildlife

21. For any surface-disturbing activities proposed in sagebrush shrublands, the Companies would conduct clearance surveys for sage grouse breeding activity during the sage grouse's breeding season before initiating the activities. The surveys must encompass all sagebrush shrublands within 0.5 mile of the proposed activities.
22. The Companies would locate compressor stations so that noise from the stations at any nearby sage grouse or sharp-tailed grouse display grounds does not exceed 49 decibels (10 dBA above background noise) at the display ground.
23. The Companies would construct power lines to minimize the potential for raptor collisions with the lines. Potential modifications include burying the lines, avoiding areas of high avian use (for example, wetlands, prairie dog towns, and grouse leks), and increasing the visibility of the individual conductors.
24. The Companies would locate aboveground power lines, where practical, at least 0.5 mile from any sage grouse breeding or nesting grounds to prevent raptor predation and sage grouse collision with the conductors. Power poles within 0.5 mile of any sage grouse breeding ground would be raptor-proofed to prevent raptors from perching on the poles.
25. The Companies would locate impoundments to avoid sagebrush shrublands, where practical.
26. Containment impoundments would be fenced to exclude wildlife and livestock. If they are not fenced, they would be designed and constructed to prevent entrapment and drowning.
27. The Companies would limit the construction of aboveground power lines near streams, water bodies, and wetlands to minimize the potential for waterfowl colliding with power lines.

Aquatics Species

28. In ponds developed where the primary objective is as a fishery, water quality would be sampled by the Companies on an annual basis for selenium, TDS, salinity, temperature, pH, dissolved oxygen, and sodium bicarbonate.
29. The Companies would fence impoundments in areas that are developed for fisheries to exclude livestock, if agreed upon with the landowner.
30. Stream channel monitoring for erosion, degradation, and riparian health would be conducted on an annual basis. Surveys would include no less than one stream reach above all CBM discharges and several stream reaches below CBM discharges. Where monitoring occurs, a station would be placed above all CBM outfalls and one below all CBM outfalls, at least on main stems.
31. Sub-watersheds that would receive CBM produced waters and would be monitored for macroinvertebrates and fish populations include: Upper Tongue River, Upper Powder River, Salt Creek, Crazy Woman Creek, Clear Creek, Middle Powder River, Little Powder River, Antelope Creek, Upper Cheyenne River, and Upper Belle Fourche River. Sam-

pling sites would be established at existing flow and water quality monitoring stations where possible. Sampling would occur on an annual basis during low-flow periods, and all data collected would be entered into a central database. Collected data may include species occurrence, species count, population demographics, and water quality and quantity measures. Fish samples may be collected and submitted for chemical analysis. Results of this analysis could be used to evaluate specific analyte concentrations in fish tissues and appropriate toxicological benchmarks. At least two sampling locations per stream or river would be established in these watersheds:

- Upper Tongue River – (1) between the Wyoming/Montana border and below all CBM discharge points; and (2) above CBM discharge points.
- Upper Powder River – (1) above Clear Creek at confluence; (2) above Crazy Woman Creek at confluence; (3) below Salt Creek at confluence; and (4) below other tributaries that may contribute flow to the Upper Powder River.
- Salt Creek – (1) above Upper Powder River at confluence; and (2) above CBM discharge points.
- Crazy Woman Creek – (1) above Upper Powder River at confluence; (2) above CBM discharge points; and (3) below other tributaries that may contribute flow to Crazy Woman Creek.
- Clear Creek – (1) above Upper Powder River at confluence; (2) above CBM discharge points; and (3) below other tributaries that may contribute flow to Clear Creek.
- Middle Powder River – (1) between the Wyoming/Montana border and below all CBM discharge points; and (2) below confluence of Upper Powder River and Clear Creek.
- Little Powder River – (1) between the Wyoming/Montana border and below all CBM discharge points; (2) above CBM discharge points; and (3) below other tributaries that may contribute flow to the Little Powder River.
- Antelope Creek – (1) between eastern boundary of the Project Area and below all CBM discharge points; (2) above CBM discharge points; and (3) below other tributaries that may contribute flow to Antelope Creek.
- Upper Cheyenne River – (1) between eastern boundary of the Project Area and below all CBM discharge points; (2) above CBM discharge points; and (3) below other tributaries that may contribute flow to the Upper Cheyenne River.
- Upper Belle Fourche River – (1) between Campbell/Crook County line and below all CBM discharge points; (2) above CBM discharge

points; and (3) below other tributaries that may contribute flow to the Upper Belle Fourche River.

- A minimum of 21 sites (as above) would need to be sampled on an annual basis to monitor aquatic health within the Project Area.

Threatened, Endangered, or Sensitive Species

32. The Companies would conduct clearance surveys for threatened, endangered or other special-concern species at the optimum time. This would require coordination with the BLM before November 1 annually to review the potential for disturbance and to agree on inventory parameters.

Bald Eagle

33. In the event that a bald eagle (dead or injured) is located during construction or operation, the USFWS' Wyoming Field Office (307-772-2374) and the USFWS' Law Enforcement Office (307-261-6365) would be notified within 24 hours.
34. Site-specific project areas would be evaluated for suitable bald eagle nesting and roosting habitat prior to permit approval. Suitable nesting habitat is any mature stand of conifer or cottonwood trees in association with rivers, streams, reservoirs, lakes or any significant body of water. Suitable roosting habitat is defined as any mature stands of conifer or cottonwood trees.
35. The BLM would monitor all take of bald eagle habitat associated with the preferred alternative. The actual measurement of disturbed habitat is the responsibility of BLM but can be delegated to BLM' agent (consultant, contractor, etc.) A written summary would be provided to the USFWS' Wyoming Field Office semi-annually. The semi-annual report would include field survey reports for endangered, threatened, proposed and candidate species for all actions covered under the *Environmental Impact Statement (EIS) for the Powder River Basin Oil and Gas Project* and ROD. The semi-annual reports would include all actions completed up to 30 days prior to the reporting dates. The first report would be due 6 months after the signing of the ROD and on the anniversary date of the signing of the ROD. Reporting would continue for the life of the project.
36. The BLM would monitor all road-associated carcasses, jackrabbit sized and larger, along project (operator-maintained) roads.
37. All power lines would be built to protect raptors, including wintering bald eagles, from accidental electrocution using methods detailed by the Avian Power Line Interaction Committee (1996).
38. Special habitats for raptors, including wintering bald eagles, would be identified and considered during the review of the APD/POD or Sundry Notices.
39. Surveys for active bald eagle nests and winter roost sites would be conducted within suitable habitat by a BLM approved biologist. Surface disturbing activities would not be permitted within one mile of suitable habitat prior to survey completion.

40. A minimum disturbance-free buffer zone of 0.5 mile (i.e., no surface occupancy) would be established year-round for all bald eagle nest sites. A seasonal minimum disturbance-free buffer zone of one mile would be established for all bald eagle nest sites (February 15 – August 15).
41. A seasonal minimum disturbance-free buffer zone of 1 mile would be established for all bald eagle winter roost sites (November 1 – April 1). These buffer zones and timing may be adjusted based on site-specific information through coordination with, and written approval from, the USFWS.
42. Within ½ mile of bald eagle winter roost sites additional measures such as remote monitoring and restricting maintenance visitation to between 9:00 and 3:00 may be necessary to prevent disturbance (November 1 – April 1).
43. Maximum design speed on all operator constructed and maintained roads would not exceed 25 miles per hour to minimize the chance of a collision with a bald eagle, other wildlife, or livestock.
44. Additional mitigation measures may be necessary if the site-specific project is determined by a BLM biologist to have adverse effects to bald eagles or their habitat.

Black-footed Ferret

45. Site-specific project areas would be evaluated for suitable black-footed ferret habitat prior to permit approval. Suitable habitat consists of a black-tailed prairie dog town or complex greater than 80 acres (USFWS 1989). A prairie dog town is a group of intact prairie dog holes whose density exceeds 8 burrows/acre; a complex consists of two or more neighboring prairie dog towns each less than 4.34 miles (7 kilometers) from the other (USFWS 1989).
46. Prairie dog colonies would be avoided wherever possible.
47. If suitable prairie dog colonies cannot be avoided, surveys would be conducted in compliance with the USFWS guidelines (USFWS 1989). The entire colony or colony complex affected would be surveyed, even if part of the colony has a burrow density below eight per acre.
48. If any black-footed ferrets are located, the USFWS would be consulted. Absolutely no disturbance would be allowed within prairie dog colonies inhabited by black-footed ferrets.
49. Additional mitigation measure may be necessary if the site-specific project is determined by a BLM biologist to have adverse effects to black-footed ferrets or their habitat. In the event that a mountain plover is located during construction or operation, the USFWS' Wyoming Field Office (307-772-2374) and the USFWS' Law Enforcement Office (307-261-6365) would be notified within 24 hours.

Mountain Plover

50. Site-specific project areas would be evaluated for suitable mountain plover nesting habitat prior to permit approval. Flat areas of short-grass prairie or low shrubs with a prevalence of bare ground characterize suit-

able mountain plover nesting habitat. Typically the vegetation height is less than 4 inches, and bare ground is greater than 30 percent.

51. The BLM would monitor all take of mountain plover habitat associated with the preferred alternative. The actual measurement of disturbed habitat is the responsibility of BLM but can be delegated to BLM' agent (consultant, contractor, etc.) A written summary would be provided to the USFWS' Wyoming Field Office semi-annually. The semi-annual report would include field survey reports for endangered, threatened, proposed and candidate species for all actions covered under the *Environmental Impact Statement (EIS) for the Powder River Basin Oil and Gas Project* and ROD. The semi-annual reports would include all actions completed up to 30 days prior to the reporting dates. The first report would be due 6 months after the signing of the ROD and on the anniversary date of the signing of the ROD. Reporting would continue for the life of the project.
52. No ground-disturbing activities would occur in suitable nesting habitat prior to surveys for nesting mountain plovers conducted in compliance with the USFWS' Mountain Plover Survey Guidelines (USFWS 2002). A BLM approved biologist would conduct the surveys. Once occupied mountain plover nesting habitat is located, the BLM would reinitiate section 7 consultation with the USFWS on any project-related activities proposed for such habitat. The amount and nature of ground-disturbing activities would be limited within identified nesting areas in a manner to avoid the abandonment of these areas.
53. Operators and the BLM would be provided by the USFWS with educational material illustrating and describing the mountain plover, its habitat needs, life history, threats, and gas development activities that may lead to incidental take of eggs, chicks, or adults with requirements that these materials be posted in common areas and circulated in a memorandum among all employees and service providers.
54. A disturbance-free buffer zone of 0.25 mile would be established around all mountain plover nesting locations between March 15 and July 31.
55. Project-related features that encourage or enhance the hunting efficiency of predators of mountain plover would not be constructed within ¼ mile of known mountain plover nest sites.
56. Construction of ancillary facilities (for example, compressor stations, processing plants) would not be located within ½ mile of known nesting areas. The threats of vehicle collision to adult plovers and their broods would be minimized, especially within breeding aggregation areas.
57. Where possible, roads would be located outside of plover nesting areas. Maximum allowed travel speed on roads within ½ mile of identified plover nesting areas would not exceed 25 mph from March 15 and July 31.
58. Maximum design speed on all operator-constructed and maintained roads would not exceed 25 miles per hour.
59. Work schedules and shift changes would be set to avoid the periods from 30 minutes before to 30 minutes after sunrise and sunset during June and July, when mountain plovers and other wildlife are most active.

60. The BLM would monitor all road-associated carcasses, jackrabbit sized and larger, along project (operator-maintained) roads. The presence of carrion could attract mountain plover predators.

61. Creation of hunting perches or nest sites for avian predators within 0.5 mile of identified nesting areas would be avoided by burying powerlines, using the lowest possible structures for fences and other structures and by incorporating perch-inhibiting devices into their design.

62. Capped and abandoned wells would be identified with markers no taller than four feet with perch inhibiting devices on the top to avoid creation of raptor hunting perches within 0.5 mile of nesting areas.

63. Reclamation of areas of previously suitable mountain plover habitat would include the seeding of vegetation to produce suitable habitat for mountain plover.

Ute Ladies'-tresses Orchid

64. Site-specific project areas would be evaluated for suitable Ute ladies'-tresses orchid habitat prior to permit approval. Suitable habitat is characterized by moist soils near springs, lakes, or perennial streams; most occurrences are in alluvial substrates along riparian edges, gravel bars, old oxbows, and moist to wet meadows in the floodplains of perennial streams (USFWS 1995).

65. Suitable habitat would be avoided wherever possible.

66. If suitable habitat for Ute ladies'-tresses cannot be avoided, surveys would be conducted in compliance with USFWS standards (USFWS 1995) by a BLM approved biologist or botanist. Surveys can only be conducted between July 20 and August 31.

67. Moist soils near wetlands, streams, lakes, or springs in the project area would be promptly revegetated if construction activities impact the vegetation in these areas. Revegetation would be designed to avoid the establishment of noxious weeds.

68. Companies operating in areas identified with weed infestations or suitable Ute ladies'- tresses orchid habitat would be required to submit an integrated pest management plan prior to APD approval. The components of the integrated pest management plans are outlined in the CBM APD and POD Preparation Guide. Mitigation would be determined on a site-specific basis and may include such measures as spraying herbicides prior to entering areas and washing vehicles before leaving infested areas. Infestation areas of noxious weeds have been identified through the county Weed and Pest Districts and are available at the Buffalo BLM office.

Transportation

69. The Companies would use gravel, water, or other dust suppressors, as needed, to reduce dust associated with facility access roads. Companies would contact the counties to ascertain the procedures to be followed.

70. The Companies would provide georeferenced spatial data depicting as-built locations of all facilities, wells, roads, pipelines, power lines, reser-

voirs, discharge points, and other related facilities to the BLM upon completion of POD construction and development.

71. Companies would contact the counties to pursue development of maintenance agreements to ensure county roads are adequately maintained for the projected increase in use.

Visual Resources

72. The Companies would complete the following measures, where practical: use existing well pads where feasible, use vegetative and topographic screening when siting well locations, avoid highwall cuts, and shield drilling rig lights.
73. Within the designated VRM Class II corridors along Interstate 90 and State Highway 14, all project facilities on BLM surface would be screened completely from these highways.
74. The Companies would mount lights at compressor stations on a pole or building and direct them downward to illuminate key areas within the facility while minimizing the amount of light projected outside the facility.

Noise

75. Increase the distance between a CBM facility and an existing noise-sensitive receptor. As shown in the analysis, noise decreases by 6 dBA with every doubling of distance from a source. For instance, if the noise were 65 dBA at 100 feet from a CBM source, the noise would decrease to 59 dBA at 200 feet from the source and to 47 dBA at 800 feet from the source.
76. Noise mufflers would be installed on the exhaust of compressor engines to reduce the exhaust noise.
77. Where noise impacts to sensitive receptors are an issue, noise levels would be required to be no greater than 50 decibels measured at a distance of one-quarter mile from the appropriate booster (field) compressors. This may require the installation of an electrical compressor motors at these locations.

78. Noise can be reduced by construction of obstacles in the direct path from the noise source to a receiver. These obstacles can be tightly spaced wood fences (no gaps in the wood panels), concrete fences, earth berms, structures, or naturally occurring hills. Care must be taken even with a tightly spaced wood fence. Even with a small opening between the individual slats on a fence can allow a pathway for noise to propagate through the opening. In fact, the noise can actually be enhanced through a small opening because the noise energy is channeled through the opening. To mitigate this problem, wood fences are generally constructed with two faces with the slats on one face overlapping the adjacent face.

Air Quality

A number of mitigation options for CBM are part of WDEQ's normal regulatory procedure. For instance, in the permitting of compressors, the agency always requires the application of BACT. The theory here is simply that given the air resource available, within technological and financial feasibility, the number of operations that can be allowed is maximized.

79. During construction, emissions of particulate matter from well pad and resource road construction would be minimized by application of water, or other dust suppressants, with at least 50 percent control efficiency. During production and maintenance, the operators would not routinely employ dust abatement procedures on roads within the Project Area. However, roads and well locations constructed on soils susceptible to wind erosion could be appropriately surfaced to reduce the amount of fugitive dust generated by traffic or other activities, and dust inhibitors (surfacing materials, non-saline dust suppressants, and water) could be used as necessary on unpaved collector, local and resource roads that present a fugitive dust problem.

➢ A variety of potential emission reduction measures (BLM 1999d) are available to further limit NO$_x$ and other air pollutant emissions. The evaluation was not intended to rank or identify a required emission reduction measure; the appropriate level of control would be determined and required by the applicable air quality regulatory agencies during the pre-construction permit process.

BLM would also continue to cooperate with existing visibility and atmospheric deposition impact monitoring programs. The need for, and the design of, additional monitoring could include the involvement of the EPA Region 8 Federal Leadership Forum and applicable air quality regulatory agencies. Based upon future recommendations, operators could be required to cooperate in the implementation of a coordinated air quality monitoring program. Oil and gas lease terms (Section 6) require the lessee, within the lease rights granted, to take measures deemed necessary by the lessor for the conduct of operations in a manner that minimizes adverse impacts to air quality, as well as other resources.

80. Table 4–98 and Table 4–99 below present mitigation options for particulate matter and nitrogen oxide emissions.

Table 4–98 Fugitive Dust Mitigation Measures (PM10), Effectiveness and Cost

	Dust Sources					
	Disturbed Areas	Unpaved Roads[1]				
Mitigation Options	Establish plant cover for all disturbed lands by certain time (re-vegetation)	Water roads to attain certain percent moisture[2]	Apply soil stabilizer	Set and enforce speed limit	Gravel roads	Paved road
Effectiveness	Level proportional to percentage of land cover	0 – 50% reduction in uncontrolled dust emissions	33 to 100% control efficiency	80% for 15 mph 65% for 20 mph 25% for 30 mph[3]	30% reduction	90% reduction
Estimated Cost	$/acre	$4000/mile	$2,000 to $4,000/mile per year	Unknown	$9,000/mile	$11,000 to $60,000/mile

Note:

1. Improved and County roads
2. Wetting of construction roads during the construction period. Wetting of construction roads not required for once a month maintenance trips to well pads.
3. Reductions assume 40 mile per hour base speed.

Table 4–99 Nitrogen Oxides (NO_x) Mitigation Measures Efficiency

	NO_x Emissions Sources			
	Field Compressors	Sales Compressors	Temporary Diesel Generators[1]	Heavy Equipment
Mitigation Options/ Efficiency	Implement Best Available Control Technology[2] Typically results in a NO_x emission rate of about 1 g/bhp-hr	Implement Best Available Control Technology[2] Typically results in a NO_x emission rate of about 1 g/bhp-hr	Register with State; will regulate as appropriate	Voluntary use of diesel engines

Notes:

1. Wyoming is currently registering these generators to determine if NO_x emissions are significant.
2. BACT could include electric compression

Unavoidable Adverse Effects

The sections below describe the unavoidable adverse effects identified during the analysis.

Groundwater and Surface Water

Unavoidable adverse effects to groundwater and surface water would occur. These effects include the long-term removal of water from the coal aquifers as they are depressurized by the wells. The volume of water in other aquifers would be increased through infiltration and injection. The quality of surface waters would change in response to the discharges of CBM produced water and disturbances of soils and vegetation throughout the Project Area.

Air Quality

Some increase in air pollutant emissions would occur as a direct result of the development alternatives; however, based on the "reasonable, but conservative" modeling assumptions, these direct impacts are predicted to be below applicable significance thresholds.

Vegetation

Unavoidable direct and indirect adverse effects would occur under each of the three alternatives. The extent of disturbance would be essentially equivalent for Alternatives 1 and 2, but would be half the magnitude for Alternative 3. Areas disturbed under each alternative would be subject to a high potential for invasion of noxious weeds and would require substantial effort to prevent and control their spread. Restoration of biodiversity in disturbed areas would require an extended period and would likely be a function of the spread of native plant species from outside of disturbed areas, a time-consuming process that can be severely delayed by invasions of noxious weeds. Vegetation types providing crucial wildlife habitats would not likely be replaced for an extended period, potentially causing adverse effects to wildlife.

Wetland/Riparian Area

Unavoidable direct and indirect adverse effects would occur under each of the three alternatives. The extent would be essentially equivalent for Alternatives 1 and 2, but about half the magnitude for Alternative 3. The primary adverse impact would be alteration of wetland/riparian areas by discharge of produced CBM water. During production, wetland/riparian areas are likely to expand, although increased water flow may also result in increased levels of erosion or sediment deposition, causing adverse impacts. As water production decreases toward the end of the project, wetland/riparian areas would contract, returning to pre-project sizes. Areas of excessive erosion or sediment deposition may cease to function as wetland/riparian areas. All of these changes in the extent of wetland/riparian areas would provide opportunities for aggressive species, including noxious weeds, to invade disturbed areas.

Wildlife

Unavoidable adverse effects would occur under each of the four alternatives. The types of impacts would be the same for each alternative. The impacts of Alternative 3 would be substantially smaller than for the other three alternatives, which would be similar in magnitude. The primary difference between alternatives is the amount of impacts from water handling methods. The extent of unavoidable adverse impacts would be greatest under Alternative 2A, followed by Alternative 2B, Alternative 1, and Alternative 3. Wildlife habitats would be degraded, lost, or fragmented. Direct mortality of wildlife because of hunting, poaching, vehicle collisions, power line collisions, or power line electrocutions would increase. Harassment and displacement would occur because of increased human activities. Habitat effectiveness, nutritional status, and reproductive success of big game species would decrease. Fugitive dust would decrease vegetative productivity along roads. Raptor predation on upland game and other wildlife species would increase. Waterfowl would be adversely affected by exposure to high levels of salts and metals in containment reservoirs. The population of many species would decline.

Threatened, Endangered, or Sensitive Species

Unavoidable adverse effects to special-status wildlife and plant species would occur under each of the alternatives. Effects to special-status wildlife species include loss of foraging and nesting habitats, harassment and displacement of individuals, and injury or mortality to individuals. Unavoidable adverse effects to special-status plant species include disturbance of individual plants, loss of suitable habitat, and introduction or spread of noxious weeds in habitats suitable to special-status plants.

Land Uses

For any of the alternatives, there would be unavoidable short-term, adverse indirect effects to the land uses on properties adjacent to the project-related facilities, resulting from noise, traffic, and dust generated by the project-related vehicles and equipment, primarily during construction-related activities within the Project Area.

Transportation

For any of the alternatives, there would also be unavoidable long-term indirect adverse effects to the properties adjacent to the major access roads within the Project Area through increased traffic, noise, and dust from project-related vehicles.

Quality of Life

Effects to quality of life may occur depending on an individual's point of view. For those who prefer the solitude and natural setting, their quality of life would be affected for the life of the project. Additionally, not drilling federal wells now may result in future negative production rates on federal minerals through depletion of minerals from drilling on state and private lands.

Human Health and Safety

A minimal increase in potential risks to human health and safety related to methane migration and seepage and pipeline ruptures is anticipated to occur because of the additional CBM facilities.

Irreversible and Irretrievable Effects

An irreversible or irretrievable commitment of resources would occur when resources would be consumed, committed, or lost as a result of the project. The

377

commitment of resources would be irreversible if the project started a process (chemical, biological, or physical) that could not be stopped. As a result, the resource or its productivity or its utility would be consumed, committed, or lost forever. Commitment of a resource would be considered irretrievable when the project would directly eliminate the resource, its productivity, or its utility for the life of the project and possibly beyond.

No irreversible or irretrievable effects would occur to air quality or visual or noise resources. The following is a listing of the effects that would occur to the other resources analyzed in this EIS.

Irreversible Effects

- Removal of natural gas
- Transfer of groundwater to surface water
- Take of individuals of special-status wildlife and plant species

Irretrievable Effects

- Loss of vegetative cover for several years until reclamation is successful
- Loss of riparian vegetation over the life of the project
- Loss of wildlife habitats beyond the life of the project, depending on the success of reclamation
- Decreased wildlife populations
- Loss of habitats for sensitive species
- Loss of livestock forage for several years until reclamation is successful
- Harassment and displacement of individuals of special-status wildlife and plant species

Chapter 5

Land Use Planning, Plan Conformance, and Proposed Plan Amendments

BLANK PAGE

Chapter 5 — Land Use Planning, Plan Conformance and Proposed Plan Amendments

Land Use Planning and Decision-Making for Management of Oil and Gas Resources

BLM RMPs

The BLM's principal authority for managing public lands is the FLPMA (PL 94-579, 43 USC 1701-1782 [Supp.1977], which directs BLM to manage public lands based upon the principles of multiple use and sustained yield in conformance with land use plans developed under the Act.

Within the Project Area, the BFO administers the BLM lands in portions of Campbell, Johnson, and Sheridan counties and the CFO administers the BLM lands within the northern portion of Converse County.

The BLM in Wyoming follows a multi-step approach to analyzing impacts and making decisions about oil and gas leasing and development. The first step occurs at the RMP/EIS stage, where land use allocations and other land use planning decisions are made. It is at this stage that lands are identified as closed to leasing, open to leasing subject to standard lease terms and conditions, open to leasing subject to minor constraints, such as seasonal restrictions, or open to leasing subject to major constraints, such as no surface occupancy. See Appendix O for more information about the current RMPs concerning areas open and closed to leasing. Lease stipulations that apply to areas open to leasing are also identified at this stage. See Appendix P for more information about leases, NEPA review, a listing of the current lease stipulations and the agencies' review of the lease stipulations. The FEIS does not consider changes to the leasing allocation decisions, as the FEIS does not address allocations decisions.

The RMP also includes decisions about other resources and describes the management goals, objectives, and management actions for the public lands in the planning area.

A site-specific NEPA analysis is completed when individual APDs, application for ROWs, or sundry notices are filed with the appropriate office of the BLM. These NEPA documents describe the analysis of the impacts of a single action or a group of wells in a POD and often tier to existing NEPA documents.

33

At each step, appropriate protective measures would be developed as part of the NEPA analysis and become mitigating measures attached as COA to individual permits and authorizations. These COA may be attached to the permit or may be submitted with the applicant's proposal as an integral part of the application. They provide the most site-specific protective measures of the multi-step authorization process. These COA must be justified in the appropriate NEPA document. COA must be consistent with the lease rights granted. The menu of possible COA can be changed as necessary to achieve the desired level of resource protection provided they are in conformance with the RMP goals and objectives. See Appendix C for the current COA.

Buffalo Field Office

Guidance for oil and gas management activities in the BFO is available from several sources. In 1985, the BFO completed an RMP, which includes land use goals for the BLM-administered public lands and federal mineral estate in the BFOA (BLM 1985c). An updated description of existing management for the Buffalo RMP was completed in April 2001(BLM 2001b). The RMP includes numerous decisions concerning oil and gas exploration and development activities, including stipulations to be applied to leases.

Since the Wyodak Coal Bed Methane Project EIS, approved November 17, 1999 and the Wyodak Drainage Environmental Assessment (EA) approved March 26, 2001, oil and gas operators have been required to implement mitigation measures contained in those environmental documents. In addition the operator is committed to the Standard "Conditions of Approval" for APDs, BLM Buffalo Field Office (see Appendix C).

Casper Field Office

The Platte River Resource Area RMP was approved in July 1985 and is implemented and monitored by the CFO. With the exception of some specified areas, BLM-administered lands in the Platte River Resource Area are open to oil and gas leasing, subject to the Wyoming BLM mitigation guidelines.

Guidance for oil and gas management activities in the CFO is available from three applicable documents as maintained: Platte River Resource Area Resource Management Plan Record of Decision (BLM, 1985); Platte River Resource Area Oil & Gas Environmental Assessment (BLM, 1982); and Southern Big Horn Mountain Oil and Gas Leasing Environmental Assessment Record (BLM, 1979).

Thunder Basin National Grassland LRMP

Numerous land parcels within the TBNG are scattered throughout Campbell and Converse counties in the Project Area. Although the Bighorn National Forest is on the western boundary of the Project Area, none of the Bighorn National Forest lands are within the Project Area. All of the CBM resources on NFS lands within the Project Area are located in the westernmost portion of the TBNG, which is administered by the Douglas Ranger District of the Medicine Bow-Routt National Forests. Oil and gas leasing and development activities on National Forest System lands within the TBNG are allowed, subject to the limitations imposed by the ROD for the 2001 LRMP for the Medicine Bow National Forest and TBNG (FS 2002). Actions proposed within the TNBG must conform to the management goals within the LRMP (FS 2001a).

The FS has released a ROD, Revised LRMP, and FEIS for the TBNG (July 2002). East of the coal outcrop line new leasing decisions are included in the July 2002 ROD. That decision deferred new oil and gas leasing decisions on the area west of the coal outcrop line until the cumulative effects of CBM development could be disclosed in this FEIS. Currently, the area west of the coal outcrop line is available for leasing under the 1994 ROD for Oil and Gas Leasing on the TBNG (FS 1994). Once the cumulative effects analysis contained in this FEIS is available, the FS will make new oil and gas leasing decisions for the area west of the coal outcrop line on the TBNG.

The FS is using the analysis documented in the Revised LRMP FEIS and in this FEIS to make two new leasing decisions for the area with CBM development potential on the TBNG. That area is defined as the TBNG area west of the Wyodak coal outcrop line. The first decision is whether lands in the Project Area are "available" or "not available" to lease and, if available, the conditions under which they are available [36 CFR 228.102 (d)]. If lands are determined to be "available" for leasing, then a second decision must be made regarding those lands: whether to authorize BLM to offer leases at this time, or to defer authorization until some future time. This determination of the specific lands to be leased is the "Leasing Decision for Specific Lands" [36 CFR 228.102 (e)].

Leasing analysis, as required by 36 CFR 228, was conducted during both the 1994 and more recent 2002 Northern Great Plains analyses. Both of these analyses developed many special stipulations to protect identified resources within FS-administered lands. The FS will include a decision on whether or not to implement the stipulations identified in the leasing analysis conducted for the 2002 Revised LRMP in the ROD resulting from this FEIS. In addition, the ROD will include a decision on stipulations and forest plan standards and guidelines needed to implement mitigation measures identified in this FEIS.

The FS also has a tiered approach to analyzing impacts and making decisions about oil and gas leasing and development. The FS oil and gas leasing decision process is codified in regulations at 36 CFR 228.

The first decision is to determine the lands administratively available for leasing [36 CFR 228.102 (d)]. Lands administratively available and not administratively available are determined in accordance with a Leasing Analysis described in 36 CFR 228.102 (c), which includes the identification of necessary constraints (leasing stipulations). The government grants no rights to other parties when the Leasing Analysis is completed and the administratively available decision is made.

The second decision is the leasing decision for specific lands [36 CFR 228.102 (e)]. This decision authorizes BLM to offer specific NFS lands for lease. Transmittal of the specific lands decision occurs when the FS has received and reviewed a request for a lease parcel report from BLM. The regulations implementing the Leasing Reform Act require the following before BLM can be authorized to offer NFS lands for lease:

1. Verifying that oil and gas leasing on the specific lands has been adequately addressed in a NEPA document and is consistent with the LRMP.
2. Ensuring that conditions of surface occupancy identified in the Leasing Analysis are properly included as stipulations in resulting leases.
3. Determining that operations and development could be allowed somewhere on each proposed lease, except where stipulations prohibit all surface occupancy.

For both the administratively available [36 CFR 228.102 (d)] and the leasing specific lands [36 CFR 228.102 (e)] decisions, the leasing analysis was primarily conducted in the FEIS for the Revised TBNG LRMP, approved July 31, 2002. New leasing decisions for NFS lands with CBM potential were deferred pending the disclosure of the cumulative effects of CBM in this FEIS.

Prior to actual drilling or subsequent oil and gas operations, a SUPO will have to be approved covering those activities. As part of the review of the SUPO, the authorized officer must comply with NEPA (36 CFR 228.107). Identified site-specific mitigation measures will be attached to the SUPO as conditions of approval.

Plan Conformance

Conformance with the RMPs

The management decisions documented in the two BLM RMPs regarding oil and gas resources provide for the continued availability of the federal lands and mineral estate for the development of federal oil and gas resources. Implementing the Proposed Action or any of the alternatives would be in conformance with the oil and gas decisions in the BLM RMPs.

The full set of resource management decisions documented in the RMPs represents a compatible blend of land uses. The RMPs for the BFO and CFO document BLM's decision to allow for development of oil and gas on federal leases as well as to take a variety of actions related to other resource values and uses. The NEPA analyses for the RMPs recognize the effects of one land use on the other.

This FEIS analyzes the social, economic and environmental effects on a variety of resources and land uses, including those addressed in the current RMPs, of a level of oil and gas development that is different than the level analyzed in the EIS for the current RMP. BLM carefully reviewed the current RMP decisions for these other resources and land uses against the description of the impacts of oil and gas development described in the FEIS to determine if the oil and gas development impacts would preclude accomplishment of the goals and objectives for non-oil and gas resources. BLM has determined that the other resource decisions could still be implemented and their objectives achieved with the level of development analyzed in the FEIS and that the land use plan decisions are not required to be changed. Even so, BLM has concluded that completing a discretionary amendment that is limited in scope would be helpful to the public and the oil and gas operators because it would consolidate the current direction for management of oil and gas resources into a single, comprehensive document. See Appendix Q for more information on this review and determination.

Conformance with the LRMP

Currently, all lands on the TBNG are available for oil and gas leasing. The area west of the Wyodak coal outcrop line is available for leasing under the 1994 ROD for Oil and Gas Leasing on the TBNG. East of the coal outcrop line new leasing (both the availability and specific lands) decisions are included in the July 2002 ROD. This analysis has identified no proposed changes to areas determined to be available for oil and gas leasing or additional special stipulations for development of CBM beyond those contained in the Revised 2001 TBNG LRMP.

This analysis did not identify a need to modify or add any Standards, Guidelines or lease stipulations to the 2001 Revised TBNG LRMP. Within the analyzed level of oil and gas development, resource management objectives for the TBNG LRMP will be achieved. Unique aspects of CBM will be adequately mitigated using COA and existing lease stipulations, lease notices, and current land use allocations in the Revised TBNG LRMP.

Proposed Plan Amendments

The BLM RMPs would be amended to: (1) allow oil and gas exploration and development at the level analyzed in the FEIS; (2) adopt the operational requirements included as a new Appendix I in the FEIS and standard conditions of approval (Appendix C in the DEIS and FEIS) that have been established over time; (3) adopt the mitigation measures developed in previous NEPA documents (referenced in Appendix C in the DEIS and included as a new Appendix M in the FEIS); and (4) adopt the new mitigation described in the FEIS (Chapter 4 in the DEIS and FEIS). In addition, the FEIS updates the NEPA analysis for the RMPs for management of oil and gas exploration and development on federal leases.

For the U.S. Forest Service, the FEIS will be used to allow oil and gas exploration and development at the level analyzed in the FEIS, update the NEPA analysis for the LRMP and adopt the 2002 LRMP stipulations for the area west of the coal outcrop line.

The Proposed Plan Amendments do not include changes to the leasing allocation decisions, as the FEIS does not address leasing.

BLANK PAGE

Chapter 6
Consultation with Others

BLANK PAGE

[redacted]

Agencies, companies, and organizations consulted by the BLM, FS, and State of Wyoming agencies cooperating in the analysis include the following:

Apache Tribe of Oklahoma
Blackfeet Tribal Business Council
BLM — Montana
Cheyenne and Arapaho Business Committee
Cheyenne River Sioux Tribal Council
Confederated Salish and Kootenai Tribal Council
Crow Creek Lakota Tribal Council
Crow Tribal Administration
Crow Tribal Council
Flandreau Santee Lakota Executive Comm.
Fort Belknap Community Council
Fort Peck Tribal Executive Board
Kiowa Tribe of Oklahoma
Lower Brule Lakota Tribal Council
Northern Arapaho Business Council
Northern Cheyenne Tribal Council
Powder River Energy Corporation
Rosebud Sioux Tribal Council
Shoshone Business Council
Sisseton-Wahpeton Lakota Tribal Council
Spirit Lake Lakota Tribal Council
Standing Rock Lakota Tribal Council
Three Affiliated Tribes Business Council
Turtle Mountain Chippewa
U.S. Environmental Protection Agency
Western Gas Resources, Inc.
Wyoming Outdoor Council
Yankton Lakota Tribe

BLANK PAGE

Chapter 7
Preparers and Contributors

BLANK PAGE

Chapter 7 Preparers and Contributors

This EIS was prepared by Greystone, a third-party contractor, under the direction of the BLM. Representatives from the cooperating agencies contributed to and participated in the NEPA process. Technical input regarding the proposed project was provide by the Companies. Table 7–1 through Table 7–6 present the names of individuals and their area or areas of responsibility from the BLM, FS, Greystone, Applied Hydrology Associates, Inc., and Argonne National Laboratories who were involved in the preparation of this EIS. Brief biographical information also is presented.

Table 7–1 U.S. Department of Interior, Bureau of Land Management

Name	Project Responsibility
Buffalo Field Office	
Paul Beels	Project Manager
Andy Ambrose	GIS
Jim Baker	Recreation Resources and GIS
Tom Bills	Wildlife and Threatened, Endangered, or Sensitive Species
Elizabeth Burghard	Cultural and Paleontological Resources
Kathy Brus	Water Resources
BJ Earl	Cultural and Paleontological Resources
Willy Frank	Minerals – Oil and Gas
Larry Gerard	Wildlife, Special Status, Fisheries, Vegetation, Wetlands, and Riparian
Janelle Gonzalez	Vegetation
Larry Grey	Water Resources
Steve Hannan	Rangeland and Grazing
Bob Hartman	Minerals- Oil and Gas
John Kolnik	Land Use
Mike McKinley	Water Resources
Jerry Queen	Geology
Brent Sobotka	Water Resources
Rob Wilson	Cultural and Paleontological Resources
Richard Zander	Document Review

BEST COPY AVAILABLE

Table 7–1 U.S. Department of Interior, Bureau of Land Management

Name	Project Responsibility
Casper Field Office	
Chris Arthur	Cultural and Paleontological
Jim Bauer	Reclamation and Minerals – Oil and Gas
Mike Brogan	Water Resources
Eve Bennett	Visual and Recreation Resources
Nancy Doelger	Minerals – Coal
Charlie Fifield	Rangeland and Grazing
Willie Fitzgerald	Wildlife, Special Status Species, Fisheries
Charlie Gaskill	Minerals – Coal
Joe Meyer	Water, Soils, and Reclamation
Glen Nebeker	General Contact/ NEPA and Planning Conformance
Randy Sorenson	Land Use
Bob Specht	Geology and Minerals
George Soehn	Vegetation, Wetlands, Riparian
Don Whyde	Recreation Resources
Wyoming State Office	
Susan Caplan	Air Quality
Roy Allen	Socioeconomics
National Science and Technology Center	
Scott Archer	Air Quality

Table 7–2 U.S. Department of Agriculture, Forest Service

Name	Project Responsibility
Joe Reddick	Project Coordination
JoAnne Homuth	Project Coordination and Review
William Steenson	NEPA Review
Melody Holm	Minerals Review
Terry Dilts	Minerals and NEPA Review

394

BEST COPY AVAILABLE

Table 7–3 State, Local, and Cooperating Agencies

Name	Agency	Position
John Robitaille	Wyoming Business Council	Minerals, Energy & Transportation Program Manager
Steve Reynolds	Wyoming Business Council	
Don Christianson	Wyoming Department of Agriculture	Director
Darla Potter	Wyoming Department of Environmental Quality	Environmental Analyst
Dennis Hemmer	Wyoming Department of Environmental Quality	Director
Gary Beach	Wyoming Department of Environmental Quality	Water Quality Division Administrator
John Wagner	Wyoming Department of Environmental Quality	
Tim Stark	Wyoming Department of Transportation	Environmental Services
Tom Collins	Wyoming Game and Fish Department	Environmental Services Coordinator
Lance Cook	Wyoming Geological Survey	State Geologist
Carol Kruse	Wyoming Office of Federal Land Policy	Planning Consultant
Julie Hamilton	Wyoming Office of Federal Land Policy	Planning Consultant
Susan Child	Wyoming Office of Federal Land Policy	Planning Consultant
Tracy Williams	Wyoming Office of Federal Land Policy	Planning Consultant
Ron Arnold	Wyoming Office of State Lands and Investments	Director
Don Likwartz	Wyoming Oil and Gas Conservation Commission	Director
Dick Stockdale	Wyoming State Engineer's Office	Deputy Engineer
Patrick Tyrrell	Wyoming State Engineer's Office	State Engineer
Richard Currit	Wyoming State Historic Preservation Office	SHPO Director

BEST COPY AVAILABLE

395

Table 7–3 State, Local, and Cooperating Agencies

Name	Agency	Position
Mike Besson	Wyoming Water Development Commission	Director
Marilyn Connolly	Johnson County Comissioner	
Brenda Schladweiler	Campbell County Conservation District	
Mickey Steward	CBMCC Coordinator	
Bill Welles	Lake DeSmet Conservation District	

Table 7–4 Greystone — Third Party Contractor

Name	Project Responsibility	Education
David Cameron	Project Manager	B.A. Biology M.S. Terrestrial Ecology 23 years of experience
Lucy Bambrey	Cultural Resources	M. A. Anthropology B.A. Sociology 22 years experience
Sue Barker	Water Resources	B.A. Environmental Biology 11 years of experience
Kathryn Cloutier	Land Use and Transportation	MS. Environmental Management/Natural Resources B.A. Biology 15 years experience
Kyle Davenport	Soils	B.S. Environmental Science 2 years of experience
Sara Davis	Biological Resources	B.S. Botany 3 years of experience
Don Douglas	Noise	M.S. Meteorology B.S. Metrology 31 years of experience
Steve Faulk	Biological Resources	M.S. Biology B.S. Biology 6 years of experience
Chuck Florian	GIS	B.S. Natural Resource Management 7 years of experience
Butch Fries	Technical Editing	M.A. Mass Communication B.A. Journalism 26 years of experience

BEST COPY AVAILABLE

396

Table 7–4 Greystone — Third Party Contractor

Name	Project Responsibility	Education
Patrick Golden	Biological Resources	B.A. Environmental Biology 7 years of experience
Mike Holle	GIS	B.S. Natural Resource Science Minor in Spatial Database Management Systems 7 yesrs of experience
Michael Jones	Biological Resources	M.S. Health Physics/Radiation Ecology M.A. Zoology/Ecology B.S. Biology 17 years of experience
Mike Kolin	Engineering	M.S. Mining Engineering Engineer or Mines 32 years of experience
John MacDonald	Biological Resources	M.S. Environmental Design B.S. Zoology 7 years of experience
Keary Mullins	Socioeconomics	B.A. Environmental Biology 6 years of experience
Matt Schweich	Biological Resources	B.S. Natural Resource Management 6 years of experience
Carl Spath	Cultural Resources	Ph.D. Anthropology M.A. Anthropology B.A. Anthropology 30 years of experience
Lisa Welch	Visual and Recreational Resources	B.S. Earth Science 10 years experience
Kathy Wilkerson	Geology, Minerals, and Water Resources	B.S. Geology 27 years of experience

Table 7–5 Applied Hydrology Associates, Inc. — Subcontractor

Name	Project Responsibility	Education
Michael Day	Project Manager for groundwater modeling	M.S. Hydrogeology B.S. Geology, math/Physics 22 years of experience
Adam Bedard	Groundwater Modeler	B.S. Civil Engineering 6 years of experience
Art O'Hayre	Surface Water Quality	Ph.D Forest Hydrology M.S. Hydrology B.S. Earth Resources/Watershed management 24 years of experience

Table 7–6 Argonne National Laboratories — Subcontractor

Name	Project Responsibility	Education
Kyong C. Chun	Air Quality Impact Assessment	Ph.D. Environmental Health Engineering 30 years of experience
Young-soo Chang	Air Quality Impact Modeling	Ph.D. Chemical Engineering 20 years of experience

396

Chapter 8
Distribution of the Final EIS

BLANK PAGE

400

Chapter 8 — Distribution and Review of the Final EIS

The following list identifies the agencies, organizations, companies, and persons to whom the FEIS was sent.

Federal and State Officials

U.S. Senator Mike Enzi

U.S. Senator Craig Thomas

U.S. Representative Barbara Cubin

Wyoming State Senator Bill Barton

Wyoming State Senator John Schiffer

Wyoming State Representative George McMurtrey, M.D.

Federal Agencies

Federal Energy Regulatory Commission

U.S. Army Corps of Engineers (multiple offices)

U.S. Department of Energy

U.S. EPA, Office of Federal Activities

U.S. EPA, Region VIII

U.S. EPA, Office of Environmental Activities

U.S. Department of Energy

USDA, Forest Service (multiple offices)

USDA, Natural Resources Conservation Service (multiple offices)

USDI, Bureau of Indian Affairs (multiple offices)

USDI, Bureau of Land Management (multiple offices)

USDI, Bureau of Land Management, Denver Federal Center

USDI, Bureau of Land Management, Division of Planning

USDI, Bureau of Reclamation (multiple offices)

USDI, Bureau of Reclamation, Denver Federal Center

USDI, Fish & Wildlife Reference Service

USDI, Fish and Wildlife Service (multiple offices)

USDI, Geological Survey (multiple offices)

USDI, Minerals Management Services

USDI, National Park Service (multiple offices)

USDI, Office of Environmental Policy and Compliance

USDI, Office of Surface Mining (multiple offices)

USDI, Office of the Solicitor
USDOD, Air Force Environmental, Safety and Occupational Health

State Agencies

Montana Department of Environmental Quality
Wyoming Office of Federal Land Policy

Local Agencies

Campbell County Conservation District
Campbell County Land Use Planning Commission
Campbell County Planning Commission
City of Gillette
Converse County Conservation District
Lake DeSmet Conservation District
Powder River Conservation District
Sheridan County Conservation District

Tribal Organizations

Apache Tribe of Oklahoma
Blackfeet Tribal Business Council
Cheyenne and Arapaho Business Committee
Cheyenne River Sioux Tribal Council
Confederated Salish and Kootenai Tribal Council
Crow Creek Lakota Tribal Council
Crow Tribal Administration
Crow Tribal Council
Flandreau Santee Lakota Executive Comm.
Fort Belknap Community Council
Fort Peck Tribal Executive Board
Kiowa Tribe of Oklahoma
Lower Brule Lakota Tribal Council
Northern Arapaho Business Council
Northern Cheyenne Tribal Council
Rosebud Sioux Tribal Council
Shoshone Business Council
Sisseton-Wahpeton Lakota Tribal Council
Spirit Lake Lakota Tribal Council

Standing Rock Lakota Tribal Council
Three Affiliated Tribes Business Council
Turtle Mountain Chippewa
Yankton Lakota Tribe

Organizations

Citizens Oil & Gas Support Center
Coal Bed Methane Coalition
Gillette Area Groundwater Monitoring Org.
Grass Roots Advocate
Natural Resources Defense Council
Petroleum Association of Wyoming
Powder River Basin Resource Council
Prairie Hills Audubon Society
Public Lands Advocacy
Sierra Club, Northern Great Plains Reg.
Wildlife Management Institute
Wyoming Outdoor Council
Wyoming Wildlife Federation

Companies

Anderman Operating Company, Inc.
Antero Energy, LLC
Argonne National Laboratories
Astrella & Rice, PC
Ballard Petroleum Holdings, LLC
Biodiversity Associates
Bjork, Lindley, Danielson, & Little
BKS Environmental Associates, Inc
Bowers Oil and Gas
Cambria Oil
Carl Underwood Oil and Gas Company
Celsius Energy Corporation
Chaco Energy Company
CMS Oil & Gas
Coleman Oil and Gas, Inc.
Daly Law Associates
Daub and Associates

BEST COPY AVAILABLE

403

Daube Company
Double Eagle Petroleum & Mining Company
Emerald Operating Company
Farleigh Oil Properties
Fence Creek Ranch
GR Consulting
Hathaway Land Services
Independent Landman
Independent Production
J.M. Huber Corp
Jacobs Ranch Mine
Jim's Water Service
Kennecott Energy Company
Lance Oil & Gas Company, Inc.
Lonabaugh and Riggs
M&K Oil Company
Marathon Oil Company
Mercury Exploration Company
Michiwest Energy, Inc.
Minerals Diversified Services
Moncrief Oil
MTG Operating
Nielson & Associates
North Fina LLC
Oilfield Compliance
Osborn Heirs Company
Padlock Ranch Company
Peak Exploration
Petroleum Development Corp.
Petrox Resources, Inc.
Pioneer Oil & Gas
Powder River Oil
Prima Oil & Gas Co.
Quantum Energy
Remington Creek, LLC
Rio Algom Mining Corp.
Sands Oil Company
Stone Energy, LLC
T. Johnson Drilling

The Termo Company
WBI Holdings, Inc.
Williams Production RMT
Woodward-Clyde Consultants
Yates Petroleum

Educational Institutions

Campbell County Public Library
Converse County Library
Johnson County Library
Natural Resources Library
Natrona County Library
Sheridan College
Univ. of WY Libraries/Collection Dept.
Wyoming, State Library

Individuals

Ingwersen, F.
Jeremiah, S.
Lorenzen, R.
Mengel, M.
Nichols, A.
Swanson, J.
Swartz, E.
Whitehead III, N.
Zimmer, R.

BEST COPY AVAILABLE

BLANK PAGE

Chapter 9

Glossary

BLANK PAGE

Chapter 9 — Glossary

Acid Neutralizing Capacity – The extent to which natural water bodies are able to buffer atmospheric deposition of sulfate or nitrate particulate matter from air pollution emission sources.

Acre-feet – The volume of liquid or solid required to cover 1 acre to a depth of 1 foot, or 43,560 cubic feet; measure used for volumes of water or reservoir rock, for example.

Adsorb – A process by which molecules are taken up on the surface of a solid by chemical or physical action. Large amounts of gases, for example, may be adsorbed on the surface of a porous material such as charcoal.

Ad valorem – A tax on items that is imposed at a rate percent of value.

Affected Environment – The natural, physical, and human-related environment that is sensitive to changes caused by proposed actions; the environment under the administration of a land management agency.

Air Dispersion Modeling – A complex computer model that calculates ambient concentrations of air pollutants.

Allotment – A unit of land suitable and available for livestock grazing that is managed as one grazing unit.

Alluvial – Deposited by a stream.

Alluvial Fan – A fan-shaped deposit of unsorted stream sand and gravel located where an ephemeral stream issues from a steep mountain valley on to a flat plain.

Alluvial Valley – A valley that contains stream-deposited silt, sand, and gravel.

Alluvium – Unconsolidated or poorly consolidated gravel, sands, and clays deposited by streams and rivers on riverbeds, floodplains, and alluvial fans.

Ambient – The environment as it exists at the point of measurement and used as a basis to measure changes or impacts.

Ambient Concentration – The mass of a pollutant in a given volume of air. It is typically measured as micrograms of pollutant per cubic meter of air.

Ancillary Facility – Additional support structures required to develop the mineral resource. In the case of CBM development, this consists of gas compressor facilities, roads, collection pipelines, and electric power lines.

Animal Unit Month – For operations that involve cows and calves, it is the amount of forage consumed by a 1,000-pound cow and calf (less than 6 months of age) over a 1-month period. It is approximately 1,050 pounds of forage.

Annulus – The space between the well casing and the boundary of the hole.

Antiquities – A general term for archaeological or paleontological resources that are at least 100 years old and that tangibly represent or have the potential to yield information on historical or prehistoric cultures or extinct plants and animals.

Aquifer – A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

Artifact – An object (usually portable) created or modified by human action.

Assemblage – A collection of rocks grouped together by age or similar origin.

Authorizing Officer – Person designated as being in the position to speak for and commit an agency to action.

Avoidance Area – An environmentally sensitive area designated by an agency. Authorizations would be granted only in cases where there is a prevailing need and no practical alternative exists, and then only with provisions to protect the sensitive resources.

Azimuth – Horizontal direction expressed as the angular distance between the direction of a fixed point and the direction of the object.

Background – The viewing area of a distance zone that lies beyond the foreground and middleground. Usually from a minimum of 3 to 5 miles to a maximum of about 15 miles from a travel route, use area, or other observer position. Atmospheric conditions in some areas may limit the maximum to about 8 miles or increase it beyond 15 miles.

Best Management Practices – A practice or combination of practices deemed the most effective and practicable (including technological, economic and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.

Big Game – Large species of wildlife that are managed for hunting.

Biotic – Pertaining to life and living organisms.

Blow Out Prevention Equipment – A series of valves on the drill rig that can close down the well in the event that the drill bit penetrates zones of extreme pressure.

Bond – Financial guarantee to ensure compliance with the Mineral Leasing Act, including complete and timely plugging of wells, reclamation of lands or adversely affected surface waters, payment of royalties, assessments, or penalties.

Broadcast Seeding – Distribution of seed by a fan spreader or by hand.

Canopy – The more or less continuous cover of branches and foliage formed collectively by the crown of adjacent trees and other woody growth.

Carbon Dioxide (CO_2) – A non-hydrocarbon, corrosive gas that occurs naturally in the gaseous phase in the natural gas reservoir or is injected into the reservoir in connection with pressure maintenance, gas cycling, or other secondary or enhanced recovery projects.

Casing – (Noun) A steel pipe that maintains the opening of a drill hole. (Verb) The act of installing pipe within a well.

Catalyst – A substance that enables a chemical reaction to proceed at a usually faster rate or under different conditions than otherwise possible.

Cation – A positive ion, which in electrolysis travels to the cathode and is discharged there.

Cement Bond Log – A geophysical log that confirms the continuous placement of cement within the annulus of the well to isolate the formation of interest and to prevent commingling of different aquifers around the casing.

Characteristic Landscape – The established landscape within an area viewed. The term does not necessarily mean a natural character, but may refer to features of the cultural landscape such as a farming community, an urban landscape, or other landscape that has an identifiable character.

Clean Air Act – Public Law 84–159, established July 14, 1955, and amended numerous times since. The Clean Air Act: establishes federal standards for air pollutants emitted from stationary and mobile sources; authorizes states, tribes, and local agencies to regulate polluting emissions; requires the agencies to improve air quality in areas of the country which do not meet federal standards; and to prevent significant deterioration in areas where air quality is cleaner than the standards. The act also requires that all federal activities (either direct or authorized) comply with applicable local, state, tribal, and federal air quality laws, statutes, regulations, standards, and implementation plans. In addition, before these activities can take place in non-attainment or maintenance areas, the federal agencies must conduct a conformity analysis (and possible determination) to demonstrate that the proposed activity will comply with all applicable air quality requirements.

Climatology – Science of climate and its causes.

Coal Bed – A seam or stratum of coal parallel to the rock stratification.

BEST COPY AVAILABLE

411

CFR – Code of Federal Regulations, the compilation of regulations adopted by federal agencies through a rule-making process.

Colluvial – Consisting of a mixture of soil and angular fragments of rock that have accumulated at the foot and on slopes of mountainsides under the influence of gravity.

Colluvium – A mixture of soil and angular fragments of rock that have accumulated at the foot and on slopes of mountainsides under the influence of gravity.

Community (plant community) – An assembly of plants living together, reflecting no particular ecological status.

Community Types (vegetation) – A group of plants living in a specific region under relatively similar conditions.

Compressor – Equipment (electrically or gas-driven) used to increase the pressure on the produced gas to move it into transmission lines or into storage.

Conglomerate – A sedimentary rock comprised of an unstratified mixture or stratified layers of cobbles, gravel, and sand.

Coniferous – Referring to a cone-bearing, usually evergreen, tree.

Contrast – The effect of a striking difference in the form, line, color, or texture of the landscape features within the area viewed.

Conveyance Loss – The percentage reduction in water volume between the time it is discharged to the surface and the time it reaches a perennial stream. This reduction in volume is due to the processes of infiltration and evaporation.

Criteria Pollutants – Air pollutants for which the U.S. Environmental Protection Agency has established state and national ambient air quality standards. These standards include particulate matter (PM_{10}), nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and volatile organic compounds (VOC).

Cubic Foot – The volume of gas contained in 1 cubic foot of space at a standard pressure base of 14.7 pounds per square inch absolute (psia) and a standard temperature base of 60 degrees Fahrenheit.

Cultural Component – The elements or attributes of a cultural resource that represent a discrete episode, occupation, or period.

Cultural Resources – The archaeological and historical remains of human occupation or use. Includes any manufactured objects, such as tools or buildings. May also include objects, sites, or geological and geographical locations that are significant to Native Americans.

Cultural Significance – Is embodied in the qualities of prehistoric or historic districts, sites, buildings, structures, or objects that meet the National Register Criteria for Evaluation (Title 36 CFR Part 60.4). The application of these criteria is explained in the National Register Bulletin 15, distributed by the National Park Service.

Cumulative Effects – As defined by Title 40 CFR Part 1508.7, cumulative effects are the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of the agency or person that undertakes the other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time.

dBA – The sound pressure levels in decibels measured with a frequency weighing network corresponding to the A-scale on a standard sound level meter. The A-scale tends to suppress lower frequencies, usually below 1,000 Hz.

Decibels (dBA) – Units for describing the amplitude of sound frequencies to which the human ear is sensitive.

Deciduous – Trees or shrubs that lose their leaves each year during a cold or dry season.

Decommissioning – Generally, removal of a facility or piece of equipment from service, or a change in status from active to inactive.

Demographic – Pertaining to the study of human population characteristics including size, growth rates, density, distribution, migration, birth rates, and mortality rates.

Desorb – To restore an adsorbed substance.

Direct Effects – As defined by Title 40 CFR Part 1508.9, these effects are caused by the action and occur at the same time and place as the action. Synonymous with direct impacts.

Direct Impact Area – An area analyzed for the effects of an action that would occur at the same place and at the same time.

Discharge – The volume of water flowing past a point per unit time, commonly expressed as cubic feet per second (cfs), gallons per minute (gpm), or million gallons per day (mgd).

Dispersed Recreation – A general term that refers to recreation use outside the developed recreation sites. This term includes activities such as scenic driving, hunting, hiking, ORV use, and biking.

Distance Zones – Areas of landscapes denoted by specified distances from the observer. Used as a frame of reference to discuss landscape characteristics or activities of man.

413

- Background (bg) – Area located from 3 to 5 miles to infinity from viewer.
- Middleground (mg) – Area located from 0.25 to 0.50 to 3 to 5 miles from the viewer.
- Foreground (fg) – The detailed landscape found within 0 to 0.25 to 0.50 mile from the viewer.

Disturbance – An event that changes the local environment by removing organisms or opening up an area, facilitating colonization by new, often different, organisms.

Disturbed Area – Area where natural vegetation and soils have been removed or disrupted.

Diversity – The distribution and abundance of different plant and animal communities and species within the area covered by a Land and Resource Management Plan.

Drainage – Natural channel that contains flowing water for some time of the year. Natural and artificial means for effecting discharge of water as by a system of surface and subsurface passages.

Drill Bit – The cutting devise used to drill a well. It is typically made of hardened steel and may contain industrial grade diamond.

Drilling Mud – The circulating fluid used to bring cuttings out of the well bore, cool the drill bit, and provide stability and pressure control in the hole. Drilling mud includes a number of additives to maintain desired viscosities and weights. Some additives that may be used are caustic, toxic, or acidic.

Earthquake – Sudden movement of the earth's crust as a result of faulting, volcanism, or other mechanisms.

Ecosystem – An interacting system of organisms considered together with their environment, for example, marsh, watershed, and stream ecosystems.

Ecotone – The boundary or transition zone between adjacent plant communities, often delineating different habitat types.

Effects – Environmental consequences as a result of a proposed or alternative action. Included are direct effects, which are caused by the action and occur at the same time and place, and indirect effects, which are caused by the action and are later in time or farther removed in distance but which are still reasonably foreseeable. Also referred to as impacts.

Endangered Species – Any species of animal or plant which is in danger of extinction throughout all or significant portions of its range and has been designated "endangered" in the *Federal Register* by the Secretary of the Interior. Disturbance of the habitat of endangered species is prohibited by the Endangered Species Act of 1973, as amended.

BEST COPY AVAILABLE

Endemic – Confined naturally to a particular geographic area. Often used in opposition to the word epidemic.

Environment – The aggregate of physical, biological, economic, and social factors that affect organisms in an area.

Environmental Analysis – An analysis of alternative actions and their predictable environmental effects, including physical, biological, economic, and social consequences and their interactions; short- and long-term effects; and direct, indirect, and cumulative effects.

Environmental Assessment – A concise public document which serves to (1) briefly provide sufficient evidence and analysis for determining whether to prepare an environmental impact statement (EIS) or a Finding of No Significant Impact; (2) aid an agency's compliance with the National Environmental Policy Act (NEPA) when no EIS is necessary; (3) facilitate preparation of an EIS when necessary.

Environmental Impact Statement – An analysis of alternative actions and their predictable environmental effects, including physical, biological, economic, and social consequences and their interactions; short- and long-term effects; and direct, indirect, and cumulative effects.

Environmental Justice – Executive Order 12898 (February 11, 1994) mandates federal agencies to identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations.

Ephemeral Drainage – A drainage area or a stream that has no base flow. Water flows for a short time each year but only in direct response to rainfall or snowmelt.

Emission – Air pollution discharged into the atmosphere, usually specified by mass per unit time.

Erosion – Detachment or movement of soil or rock fragments by water, wind, ice, or gravity. Accelerated erosion is much more rapid than normal, natural or geologic erosion, primarily as a result of the influence of activities of man, animals, or natural catastrophes.

Evaluation (National Register) – The informed assessment of the qualities of a cultural resource in terms of a defined historic context in order to assess whether or not the resource is eligible for the National Register of Historic Places, and is therefore a historic property.

Exploration – The search for economic deposits of minerals, ore, and other materials through geology, geochemistry, geophysics, drilling, and mapping.

Fault – A fracture in bedrock that has undergone vertical or horizontal movement caused by differential forces in the earth's crust.

45

BEST COPY AVAILABLE

Faulting – Relative displacement of adjacent bedrock along a fracture.

Fisheries – Streams and lakes used for fishing.

Fisheries Habitat – Streams, lakes, and reservoirs that support fish.

Flaring – The controlled ignition of natural gas at a wellhead.

Floodplain – The portion of a river valley, adjacent to the channel, that is built of recently deposited sediments and is covered with water when the river overflows its banks at flood stages.

Fluvial – Comprehensive term for river processes.

Footprint – The actual surface area physically disturbed by oil and gas operations and ancillary facilities.

Forage – Vegetation used for food by wildlife, particularly big game and domestic livestock.

Forb – A broad-leaved, flowering plant.

Foreground-Middleground – The area visible from a travel route, use area, or other observer position to a distance of 3 to 5 miles. The outer boundary of this zone is defined as the point where the texture and form of individual plants are no longer apparent in the landscape and vegetation is apparent only in pattern or outline.

Fracturing – A method of stimulating well production by increasing the permeability of the producing formation. Fracture fluids, which include propping agents such as sand or glass beads, are pumped into the formations under extremely high hydraulic pressure. The propping agents facilitate the formation of channels to release water and gas into well.

Fugitive Dust – Airborne particles emitted from any source other than through a controllable stack or vent.

Game Species – Animals commonly hunted for food or sport.

Gas Venting – The release of gas into the atmosphere after well development and before successful installation of the collection pipeline.

Geotechnical – A branch of engineering concerned with the design aspects of slope stability, settlement, earth pressures, bearing capacity, seepage control, and erosion.

Glacial Outwash – The material deposited by streams flowing within a glacier and by melt-waters during times of glacial advance and retreat.

Grade – A slope stated in terms of feet per mile or as feet per feet (percent); the content of precious metals per volume of rock (ounces per ton).

Groundwater – All subsurface water, especially as distinct from surface water in the zone of saturation.

Habitat – The place or type of site where a plant or animal naturally or normally lives and grows. Includes all biotic, climatic, and soils conditions, or other environmental influences that affect living conditions.

Habitat Diversity – The distribution and abundance of various plant and animal communities and species within a specific area.

Habitat Fragmentation – The process that increasingly subdivides habitats into smaller units, resulting in their increased isolation as well as loss of total habitat area.

Habitat Type – The aggregate of all areas that support or can support the same primary vegetation at climax.

Herbaceous – The plant strata that contain soft, not woody, stemmed plants that die to the ground in winter.

Historic Context – Defined historical or traditional patterns or trends of a discrete theme or period of history or prehistory within which an event, site, object, or class of objects can be understood and compared with similar or related events, sites, or objects.

Historic Landscape – A type of historic district that is a geographic area, or the sites, buildings, structures, natural and cultural features, and objects within a defined geographic area, that together represents a defined historic or prehistoric theme and period. The definition of a historic landscape includes: (1) a significant theme (linkage or continuity) such as a specific economic activity or ethnic group, (2) definitions of the sites, buildings, structures, natural features, cultural landscape modifications, and objects (property types) that represent the theme, and (3) a cultural period or range of dates.

Historic Property. – Any cultural resource that is listed on or eligible for the National Register of Historic Places under the National Register Criteria (Title 36 CFR Part 60.4[a-d]).

Hydrogen Sulfide (H_2S) – A flammable, poisonous, corrosive gas with an odor that suggests rotten eggs, which can occur naturally in the gaseous phase in natural gas reservoirs.

Hydrology – A science that deals with the properties, distribution, and circulation of surface and subsurface water.

Hydrostatic Testing – Testing the integrity of a newly placed, but uncovered, pipeline for leaks. The pipeline is filled with water and pressurized to operating pressures, and the pipeline is visually inspected.

Impoundment – The accumulation of water in a reservoir or other storage area.

417

Indemnify – To secure against, or to provide compensation for incurred loss, hurt, or damage.

Indirect Effects – As defined by Title 40 CFR Part 1508.8, these effects are caused by the action but occur later in time or are removed in distance from the action, but are still reasonably foreseeable. Synonymous with indirect impacts.

Infiltration – The movement of water or some other liquid into the soil or rock through pores or other openings.

Infrastructure – The basic framework or underlying foundation of a community, including road networks, electric and gas distribution, water and sanitation services, and facilities.

Injection Well – Any well used for the disposal of air, gas, water, or other substance into any underground stratum.

In Situ – The quality of being in place, typically referring to an object still being in the location where it was left or deposited after the activity or event with which it is associated. The concept implies that the object, or set of objects, retains spatial and functional association with other related materials.

Intermittent Stream – A stream that flows only at certain times of the year when it receives water from alluvial groundwater, springs, or from some surface source such as melting snow in mountainous areas.

Irretrievable – Applies to the loss of production, harvest, or use of natural resources. For example, some or all of the timber production from an area is lost irretrievably while an area is serving as a winter sports site. The production lost is irretrievable, but the action is not irreversible. If the use changes, it is possible to resume timber production.

Irreversible – Applies primarily to the use of nonrenewable resources, such as minerals or cultural resources, or to factors that are renewable only over long time spans, such as soil productivity and aspen regeneration. Irreversible also includes loss of future options.

Isolated Find – A single or conjoinable historic or prehistoric artifact that was found at least 30 meters from any other historic or prehistoric object or feature with which it could reasonably be associated.

Landform – Any physical, recognizable form or feature of the Earth's surface, with a characteristic shape and produced by natural causes. Includes major features such as plains, plateaus, and mountains, and minor features, such as hills, valleys, slopes, canyons, arroyos, and alluvial fans.

Landscape Character – The arrangement of a specific landscape as formed by the variety and intensity of the landscape features, as defined as the four basic elements (form, line, color, and texture). These factors give the area a distinctive quality that distinguishes it from its immediate surroundings.

Landslide – A perceptible downhill sliding or falling of a mass of soil and rock lubricated by moisture or snow.

Land Use – Land uses identified for a specific area that establish the types of activities allowed (for example, mining, agriculture, timber production, residential, or industrial).

Lease – Any contract, profit-share arrangement, joint venture, or other agreement issued or approved by the United States under a mineral leasing law that authorizes exploration for, extraction of, or removal of oil or gas.

Lek – An area used by sage grouse for mating displays (strutting ground).

Lithic Scatter – Is a surface scatter of cultural artifacts and debris that consists entirely of lithic (stone) tools and chipped stone debris. This type is a common prehistoric site that is contrasted to a cultural material scatter, which contains other or additional artifact types such as pottery or bone artifacts, to a camp that contains habitation features, such as hearths, storage features, or occupation features, or to other site types that contain different artifacts or features.

Loam – A mixture of sand, silt, and clay that contains between 7 and 27 percent clay, 28 to 50 percent silt, and less than 50 percent sand.

Locus – Is a discrete place or physical location generally used in describing the qualities of a site. When the term is used in contrast to a site, it refers to a locality that contains the traces of a brief, limited, or transient cultural activity.

Long-Term Impacts - As used in the Powder River Oil and Gas NEPA analysis, long-term effects generally last beyond the construction period.

Macroinvertebrates – Aquatic invertebrate animals that live on or in the surface of the substrate of streams or lakes.

Management Area – An area composed of aggregate pieces of land (generally several to many analysis areas) where specific management objectives and prescriptions are applied.

Management Direction – A statement of multiple use and other goals and objectives, along with the associated management prescriptions and standards and guidelines to direct resource management.

Median – A value in an ordered set of values above and below which there are an equal number of other values.

Mesic – A habitat characterized by moderate moisture and temperature conditions and by a profusion of plant life.

Methane (CH_4) – The simplest hydrocarbon; natural gas is nearly pure methane.

VA

Mitigate – To lessen the severity.

Mitigation – Actions to avoid, minimize, reduce, eliminate, or rectify the impact of a management practice.

Modified Mercalli Intensity Scale – A qualitative measurement scale that describes the intensity (degree of shaking) felt by people, structures, and the ground. Intensities range from I (felt by few, if any, people) to XII (total damage).

Monitor – To systematically and repeatedly watch, observe, or measure environmental conditions to track changes.

Monoculture – An area characterized by vegetation that consists of a single species, such as a wheat field.

Mottled – Marked by different shaded spots.

National Ambient Air Quality Standards (NAAQS) – The allowable concentrations of air pollutants in the air specified by the federal government. The air quality standards are divided into primary standards (based on the air quality criteria and allowing an adequate margin of safety and requisite to protect the public health) and secondary standards (based on the air quality criteria and allowing an adequate margin of safety and requisite to protect the public welfare from any unknown or expected adverse effects of air pollutants).

National Register of Historic Places – A list, maintained by the National Park Service, of areas that have been designated as being of historical significance.

Native Species – Plants that originated in the area in which they are found, in other words, they naturally occur in the area.

Natural Gas – Those hydrocarbons, other than oil and other than natural gas liquids separated from natural gas, which occur naturally in the gaseous phase in the reservoir and are produced and recovered at the wellhead in gaseous form. Natural gas includes coal bed methane.

National Environmental Policy Act – The National Environmental Policy Act of 1969 is the national charter for protection of the environment. NEPA establishes policy, sets goals, and provides means for carrying out the policy. Regulations at Title 40 CFR Parts 1500–1508 implement the act.

Nesting Substrate – The site where a nest is placed, such as a tree, cliff, or ground.

Noxious Weeds – An alien, introduced, or exotic undesirable species that is aggressive and overly competitive with more desirable native species.

Ozone – A molecule that contains three oxygen atoms (O_3) produced by passage of an electrical spark through air or oxygen (O_2).

Pan Evaporation – A measurement of water loss to the atmosphere from a standard evaporation pan with a diameter of 47.5 inches and a depth of 10 inches.

Paleontology – The science that deals with the history and evolution of life on earth.

Particulate Matter – A particle of soil or liquid matter (soot, dust, aerosols, fumes, and mist).

Passerine – A taxonomic order that includes perching birds and songbirds.

Peak Flow – The highest flow attained when winter snowpack melts or during a large precipitation event.

Perennial – A plant with a life cycle that lasts longer than 2 years. The tops of herbaceous perennials die down at the end of the growing season, but buds, roots, and other underground portions persist.

Perennial Stream – A stream or reach of a stream that flows throughout the year.

Permeability – The capacity of a soil or groundwater aquifer to transmit water.

Permeable – The property or capacity of a porous rock, sediment, or soil to transmit a liquid.

pH – The negative $\log_{10}$ of the hydrogen ion activity in solution; a measure that indicates whether a solution is acid or base.

Physiographic – Pertaining to the genesis and evolution of landforms.

PM_{10} – Airborne suspended particles with an aerodynamic diameter of 10 microns or less.

Porosity – The voids or openings in geological materials.

Potentiometric Surface – A surface that represents the total head in an aquifer; it represents the height of the water level in tightly cased wells that penetrate the aquifer.

Prevention of Significant Deterioration (PSD) – A regulatory program under the Clean Air Act (Public Law 84-159, as amended) to limit degradation of air quality in areas that currently achieve the National Ambient Air Quality Standards. The PSD program established air quality classes that allow differing amounts of additional air pollution above a legally defined baseline level. Almost any additional air pollution would be considered significant in PSD Class I areas (certain large national parks and wilderness areas in existence on August 7, 1977, and specific tribal lands redesignated since then.) PSD Class II areas allow deterioration associated with moderate, well-controlled growth (most of the country). Although Class III areas would allow greater incremental impacts planned individual growth, no Class III areas have been established.

Produced Water – Formation water pumped during development of a gas well.

Productivity – In reference to vegetation, productivity is the measure of live and dead accumulated plant materials.

Range – Land that produces native forage for animal consumption and lands that are revegetated naturally or artificially to provide forage cover that is managed like native vegetation, which are amenable to certain range management principles or practices.

Raptor – A bird of prey with sharp talons and strongly curved beaks that preys on living animals. (The category includes eagles, hawks, falcons, and owls.)

Reach – (1) Most generally, any specified length of a stream, channel, or conveyance. (2) A length of channel that is uniform in its discharge depth, area, and slope; a relatively homogenous length of stream having a similar sequence of characteristics. (3) A length of channel for which a single gage affords a satisfactory measure of the stage and discharge. (4) The length of a river between two gaging stations.

Recharge – Replenishment of the water supply in an aquifer through the outcrop or along fracture lines.

Reclamation – The process of restoring disturbed areas using any of several methods: recontouring, spreading topsoil or growth medium, seeding, and planting, among others.

Recontouring – Restoration of the natural topographic contours by reclamation measures, particularly in reference to roads.

Record of Decision – A decision document for an environmental impact statement or supplemental EIS that publicly and officially discloses the responsible official's decision regarding the actions proposed in the EIS and their implementation.

Recreation Opportunity Spectrum Settings – A system of measuring the land's ability to meet the expectations of recreation users. Six recreation categories, from primitive (natural) to urban (highly modified) describe the activities, settings, and experiences an area offers. The following categories may be found in or near the analysis area:

- Urban – A highly modified environment, although the background may include natural elements. Sights and sounds of man predominate, and large numbers of users can be expected.

BEST COPY AVAILABLE

- Rural – An area characterized by the sights and sounds of rural residential and agricultural land uses. The interaction between users is often moderate to high.
- Roaded Natural – A road corridor with a landscape that is characterized as natural or natural appearing. The road has moderate to high use.
- Semi-Primitive Motorized – A natural area predominantly unmodified by man. There are opportunities for isolation from the sights and sounds of man, but occasional evidence of other area users is visible.

Recreation Visitor Day – A measurement equivalent to one person recreating for 12 hours or several people for a total of 12 hours.

Reserve Pit – A pit prepared on a well pad before drilling to use for retention, evaporation, and disposal of wastewater. Wastewaters will contain a component of fine solids.

Reserves – Identified resources of mineral-bearing rock from which the mineral can be extracted profitably with existing technology and under present economic conditions.

Residuum – Unconsolidated material that accumulates by weathering of parent material in place.

Resources (Geologic) – Reserves plus all other mineral deposits that may eventually become available – either known deposits that are not recoverable at present, or unknown deposits that may be inferred to exist but have not yet been discovered.

Riffle – A shallow section of stream with rapid current and a surface broken by gravel, rubble, or boulders.

Rights-of-Way – An accurately located strip of land with a defined width, point of beginning, and point of ending. The user has authority to conduct operations in this area as approved or granted by the landowner in an authorizing document, such as a permit, easement, lease, license, or Memorandum of Understanding.

Riparian – Land areas that are directly influenced by water. They usually have visible vegetative or physical characteristics showing this influence. Streamsides, lake borders, or marshes are typical riparian areas.

Riparian Ecosystem – A transition between the aquatic ecosystem and adjacent upland terrestrial ecosystem; identified by characteristics of the soil and distinctive vegetation communities that require free or unbounded water.

Rockfall – Rapid fall of a detached piece of bedrock from a cliff or steep slope.

Roosting – To rest or sleep in a roost. A bird will typically use the same roost over an extended period of time.

Runoff – The part of precipitation that appears in surface streams. The term describes precipitation that is not retained on the site where it falls and is not absorbed by the soil.

Salmonidae – A family of fish that includes salmon and trout.

Salmonid Spawning Areas – Waters that provide or could provide a habitat for active, self-propagating populations of salmonid fishes.

Scatter (archeological) – Random evidence of prior disturbance that is distributed about an area rather than concentrated in a single location.

Scoping – Procedures agencies use to establish the extent of analysis necessary for a proposed action, (the term includes the range of actions, alternatives, and impacts to be addressed; identification of significant issues related to a proposed action; and the depth of environmental analysis, data, and task assignments needed).

Sedge – Plants that resemble grasses but have hollow rather than woody stems.

Sediment – Soil or particles of rock that have been transported to stream channels or other bodies of water. Sediment input comes from natural sources, such as erosion of soil, weathering of rock, agricultural practices, or construction.

Sediment Load – The amount of sediment (sand, silt, and fine particles) carried by a stream or river.

Sedimentary – Rock formed from fragments of pre-existing rocks (such as sandstone) or by precipitation from solution (for example, limestone).

Seedling – A newly germinated plant.

Seismic – Pertaining to or produced by earthquakes.

Sensitive Species – designation used by BLM and FS applied to species that may become endangered or extinct in the state.

Sensitivity Level – A degree or measure of viewer interest in the scenic qualities of the landscape. Three levels of sensitivity have been defined:

- Sensitivity Level 1 – The highest sensitivity level, referring to areas seen from travel routes and use areas with moderate to high use.
- Sensitivity Level 2 – An average sensitivity level, referring to areas seen from travel routes and use areas with low to moderate use.
- Sensitivity Level 3 – The lowest sensitivity level, referring to areas seen from travel routes and use with low use.

Seven-day, 10-year low flow (7Q10) – The minimum flow averaged over seven consecutive days that is expected to occur on average, once in any 10-year period. The 7Q10 has a 10-percent chance of occurring in any given year.

424

Short-Term Impacts – As used in the Powder River Basin Oil and Gas NEPA analysis, short-term impacts are generally defined as effects that would occur during the construction period.

Shut In – Refers to a well that is completed, is shown to be capable of production in paying quantities, and is not currently being operated.

Significant – As used in NEPA, the determination of significance requires consideration of both context and intensity. Context means that the significance of an action must be analyzed in several contexts such as society as a whole, and the affected region, interests, and locality. Intensity refers to the severity of impacts (Title 40 CFR Part 1508.27).

Slump – Slide or earthflow of a soil mass.

Soil – Loose, unconsolidated surface material that makes up topsoil and subsoil.

Spawning – The deposition of eggs and sperm by fish.

Special Status Species –Species of plants or animals that have appeared in the *Federal Register* as federally endangered, threatened, or proposed species under the Endangered Species Act; species identified by the Bureau of Land Management (BLM) or U.S. Forest Service (FS) as sensitive species, or species on an official state list

Species – Organisms that successfully reproduce among themselves and cannot reproduce successfully with other organisms.

Species of Special Concern – A native species designed by a state wildlife agency because its population is low and limited in distribution or because it has suffered significant reductions as a result of habitat loss.

Specific Conductance (measured in microhmos per centimeter, abbreviated µmhos/cm) – A measure of electrical conductivity in water that is influenced by the mineral content of the water.

Stormwater Runoff – Overland runoff from snowmelt or a precipitation event.

Strata – An identifiable layer of bedrock or sediment; the term does not imply a specific thickness of rock.

Stratified – The quality of sediments or cultural deposits composed of or in the form of layers (strata) that represent distinguishable episodes or periods. A stratum formed by a more recent episode will lie above an older stratum formed in the same location (superposition).

Substrate – Material that consists of silts, sands, gravels, boulder and woody debris found on the bottom of a stream channel.

Target formation – The geological association of rocks that contain the exploitable mineral reserves.

Telemetry – Instrumentation to transmit scientific equipment readings from remote locations to a central site.

Threatened Species – Any species of animal or plant that is likely to become endangered within the near future throughout all or significant portions of its range. It has been designated in the *Federal Register* by the Secretary of the Interior as a threatened species. Disturbance of the habitat of threatened species is prohibited by the Endangered Species Act of 1973, as amended.

Thrust Faulting – Low-angle fracturing of bedrock in response to horizontal stress within the earth's crust

TMDL (Total Maximum Daily Load) – The limitations on the introduction of pollutants to a waterbody are identified through development of a TMDL under Section 303(d) of the Clean Water Act. A TMDL includes both a wasteload allocation (WLA), which focuses on point sources, and a load allocation (LA), which addresses non-point sources.

Total Dissolved Solids – Total amount of dissolved material, organic or inorganic, contained in a sample of water.

Total Suspended Solids – Amount of undissolved particles suspended in liquid.

Transmissivity – The rate water is transmitted through a unit width of a groundwater aquifer or confining bed under a unit hydraulic gradient.

Turbidity – A measurement used in fisheries of the total suspended solids in water expressed as nephelometric turbidity units (NTU).

Understory – The trees and other woody species that grow under a more or less continuous cover of branches and foliage formed collectively by the upper portion of adjacent trees and other woody growth.

Variety Class – A specific level of visual variety or diversity of landscape character. There are three variety classes: A, B, and C.

- Variety Class A – distinctive
- Variety Class B – common
- Variety Class C – minimal

Vegetation – All of the plants that grow in and characterize a specific area or region; the combination of the various plant communities found there.

Very High Frequency Omnidirectional Range (VOR) – Refers to VOR radio navigation aid facilities for aircraft. These facilities often are located near airports and involve height restrictions for development.

Visual Resource – The composite of basic terrain, geologic features, water features, vegetation patterns, and land use effects that typify a land unit and influence the visual appeal of the unit for viewers.

Visual Resource Management System – The BLM system for evaluating and classifying visual resources. The system uses line, form, color, texture, scale, and space to categorize lands into one of four classes:

- Class I. Preservation
- Class II. Retention
- Class III. Partial Retention
- Class IV. Modification

Water Quality – Refers to a set of chemical, physical, or biological characteristics that describe the condition of a river, stream, or lake. The quality of water determines the beneficial uses it can support. Different instream conditions or levels of water quality are needed to support different beneficial uses.

Waters of the United States – A jurisdictional term from Section 404 of the Clean Water Act that refers to water bodies such as lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, where the use, degradation, or destruction could affect interstate or foreign commerce.

Watershed – All of the land that drains surface water to a specific stream above a designated point (usually its mouth); also called a stream drainage or drainage basin.

Well Head – The equipment used to maintain surface control of a well. It is composed of the casing head, tubing head, and a series of valves and fittings.

Well Pad – A level area constructed to drill a well.

Wetlands – Areas that are inundated by surface or groundwater with a frequency sufficient to support and under normal circumstances does or would support a prevalence of vegetation or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction.

Winter Range – The place where migratory (and sometimes non-migratory) animals congregate during the winter.

Workover – Well maintenance that requires on-site mobilization of a drill rig to repair the well bore equipment (casing, tubing, rods, or pumps) or the wellhead. In some cases, a workover may involve development to improve production from the target formation.

BLANK PAGE

Chapter 10
References Cited

BLANK PAGE

Chapter 10 — References Cited

Adamus, P. R. 1996. Bioindicators for assessing ecological integrity of prairie wetlands. EPA/600/R-96/082. Corvallis, Oregon: U.S. Environmental Protection Agency, Environmental Research Laboratory.

Advanced Resources International. 2002. Personal communication [*July* memorandum to P. Lagiovanne, U.S. Department of Energy, National Energy Technology Laboratory. *RE:* CBM-Type Wells for the Powder River Basin].

AirNav.com. 2001. Airport Information for County Airports [Web Page]. Located at http://www.airnav.com/airports/us/wy. Accessed: August 25, 2001.

Air Resource Specialists, Inc. 2002. Standard Operating Procedures and Technical Instructions for Transmissometer Systems. Prepared for the IMPROVE Steering Committee. Fort Collins, Colorado. (http://vista.cira.colostate.edu/improve/Publications/SOPs/arssop.asp)

Aldrich, J. R., Flack, S. R., Fries, J., Haddock, R. Ivey, G., Lawson, K. J., Laurenzi, A., Lynett, K., Master, L. L., Myers, J., Riordan, R. M., Stein, B. A., Vaughn, C., and D. Vosick. 1998. Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity. Master, L.L., Flack, S.R., and B.A. Stein, eds. Publishers Printing Company Inc., Shepherdsville, Kentucky.

Allwine, K. J., W. F. Dabbert, and L. L. Simmons. 1998. Peer Review of the CALMET/CALPUFF Modeling System. EPA Contract No. 68-D-98-092, Work Assignment No. 1-03, dated April29, 1998. Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. (http://www.epa.gov/scram001/7thconf/calpuff/calpeer.pdf)

Almand, J. D., and W. B. Krohn. 1978. The position of the BLM on the protection and management of riparian ecosystems. Pages 359–361 *in* Strategies for protection and management of floodplain wetland and other riparian ecosystems. USDA Forest Service General Technical Report WO-12. Washington, D.C.

Applied Hydrology and Associates. 2000. Evaluation of CBM Water Discharges for Compliance with Agricultural Use Water Quality, Main Stem Study Tier 1 Report. Unpublished report. Denver, Colorado.

Applied Hydrology and Associates. 2001a. Cumulative Impacts of Coal Bed Methane Development on Water Quality in the Powder and Little Powder Rivers. Unpublished report. Denver, Colorado.

Applied Hydrology and Associates. 2001b. Powder River Basin Environmental Impact Statement. Stream Channel Characterization and Conveyance Loss Studies. Unpublished report. Denver, Colorado.

Applied Hydrology and Associates and Greystone Environmental Consultants. 2002. Technical Report for the Powder River Basin Oil and Gas Project, Groundwater Modeling of Impacts Associated with Mining and Coalbed Methane Development in the Powder River Basin. Unpublished report. Denver, Colorado.

Argonne National Laboratories. 2001. Air Quality Technical Report for the Powder River Basin Oil and Gas Project Environmental Impact Statement. Prepared for the U.S. Department of the Interior, Bureau of Land Management, Cheyenne, Wyoming. Environmental Assessment Division, Argonne National Laboratory. Argonne, Illinois.

Argonne National Laboratory. 2002. Technical Support Document – Air Quality Impact Assessment for the Montana Statewide Final Oil and Gas EIS and Amendment of the Powder River and Billings Resource Management Plans and the Wyoming Final EIS and Planning Amendment for the Powder River Basin Oil and Gas Development Project. Prepared for the U.S. Department of the Interior, Bureau of Land Management, Montana and Wyoming State Offices, by the Environmental Assessment Division, Argonne National Laboratory. Argonne, Illinois.

Asher, J., and Carol S. 1998. The Spread of Invasive Weeds in Western Wildlands: A State of Biological Emergency. The Governor's Idaho Weed Summit, Boise, Idaho. May 19, 1998. Web address http://www.blm.gov/weeds/boisummi.wpd.html

Associated Press. 2001. Methane Dams Get High Praise. *Billings Gazette*. Tuesday, July 17.

Avian Power Line Interaction Committee. 1994. Mitigating Bird Collisions with Power Lines: The State of the Art in 1994. Edison Electric Institute. Washington, D.C.

Avian Power Line Interaction Committee. 1996. Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996. Edison Electric Institute/Raptor Research Foundation, Washington, D.C. 155 Pages and appendices.

Ayers, R. S., and Westcot, D. W. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage. Paper 29 (Rev 1). Food and Agriculture Organization of the United Nations. 174 pages.

Babb, C. S. 1998. Hydrology Specialist Report for the Thunder Basin National Grasslands Environmental Assessment, Barrett Resources Corporation Black Thunder Coal Bed Methane Project. Unpublished report.

Bain, M. B. and J. T. Finn. 1988. Streamflow regulation and fish community structure. Ecology. 69: 382-392.

Barbour, M. T., Gerritsen, J., Snyder, B. D., and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency. Office of Water, Washington, D.C.

Barnard Dunkelberg and Company. 1996. Sheridan County Airport Master Plan Update. Prepared for Sheridan County, Wyoming. December.

Barrett, N. M. 1998a. Golden Eagle. Pages 124-125 *in:* Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Barrett, N. M. 1998b. Osprey. Pages 104-105 in: Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Barrett, N. M. 1998c. Sandhill Crane. Pages 162-163 *in*: Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Bartos, T. T. and K. M. Ogle. 2002. Water Quality and Environmental Isotopic Analyses of Ground-Water Samples Collected from the Wasatch and Fort Union Formations in Areas of Coalbed Methane Development – Implications to Recharge and Ground-Water Flow, Eastern Powder River Basin, Wyoming. U.S. Geological Survey Water-Resources Investigations Report 02–4045, 88 pages.

Bauder, J. W. 2002. Quality and Characteristics of Saline and Sodic Water Affect Irrigation Suitability. The Montana State University at Bozeman Department of Land Resources and Environmental Sciences Water Quality and Irrigation Management. [Website] Located at: http://waterquality.montana.edu/docs/methane/sodicirrigation.shtml. Accessed August 6, 2002.

Baxter, G. T. and J. R. Simon. 1970. Wyoming Fishes. Bulletin No. 4, Wyoming Game and Fish Department, Cheyenne, Wyoming.

Baxter, G. T., and M. D. Stone. 1985. Amphibians and Reptiles of Wyoming. Second edition. Wyoming Game and Fish Department, Cheyenne Wyoming.

Baxter, G. T., and M. D. Stone. 1995. Fishes of Wyoming. Wyoming Department of Game and Fish, Cheyenne, Wyoming.

Beauvais, G. P. 2001. Preble's meadow jumping mouse (*Zapus hudsonius preblei*) in Wyoming: Status Report, July 2001. Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming.

433

Beck, A. 2002. The Analysis of Campbell County Crime Data for the Years 1900-2001, and Examination of the Growth of Crime During the Time of Development of Coal Bed Methane. Justice Concepts Incorporated, Kansas City, Missouri. 15 Pages.

Bedard, A. 2001. Personal communication [*August 22* e-mail to C. Florian, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Groundwater wells file for the Powder River Basin EIS]. Groundwater Specialist, Applied Hydrology and Associates, Denver, Colorado.

Bell, L.H. 1982. Industrial Noise Control, Fundamentals and Applications, Marcel Dekker, New York, New York. 127 pages.

Bell, D. 2002. Personal Communication [*July 23* telephone conversation with K. Mullins, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Hutterite Colony locations and Populations]. Montana Department of Revenue, Forsyth, Montana.

Benjamin, R. 2002. Sheridan County Weed and Pest Control District. [*September 3* telephone conversation with C. Florian, Greystone Environmental Consultants, Greenwood Village, Colorado].

Bernstein, L. 1964. Salt Tolerance of Plants. U.S. Department of Agriculture Information Bulletin 283. U.S. Government Printing Office. Washington, D.C.

Birnbaum, C. A., editor. 1996 The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for the Treatment of Cultural Landscapes. U.S. Department of the Interior National Park Service, Cultural Resource Stewardship and Partnerships, Heritage Preservation Services, and Historic Landscape Initiative, Washington, DC.

Blatt, H., G. Middleton, and R. Murray. 1972. Origin of Sedimentary Rocks. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 604 pages.

Boggs, J. P. 2002. Northern Cheyenne Subsistence Survey. Northern Cheyenne Reservation, Missoula, Montana. 6 Pages.

Boyd, C. S., A. J. Ver Ploeg, A. L. Kirkaldie, and C. A. Jessen. 1999. Digital Geologic Map of the Gillette 30' x 60' Quadrangle, Campbell, Crook, and Weston Counties, Northeastern Wyoming. Wyoming State Geological Survey, Geologic Hazards Section Digital Map 99–1 (HSDM 99–1).

Boyle, S. 1998a. Short-eared Owl. Pages 226-227 *in:* Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Boyle, S. 1998b. Great Horned Owl. Pages 216-217 *in:* Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

434

BEST COPY AVAILABLE

Bradshaw, B. 1996a. Powder River Basin Management Plan (FXSN8PR). Wyoming Game and Fish Department, Sheridan. Wyoming.

Bradshaw, B. 1996b. Cheyenne River Basin Management Plan (FXSN8CR). Wyoming Game and Fish Department. Sheridan, Wyoming.

Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. Wildlife Society Bulletin 5(3): 99–106.

Braun, C. E., O. O. Oedekoven, and C. L. Aldridge. In press. Oil and Gas Development in Western North America: Effects on Sagebrush Steppe Avifauna with Particular Emphasis on Sage Grouse.

Breckenridge, R. M., G. B. Glass, F. K. Root, and W. G. Wendell. 1974. Geologic Map Atlas and Summary of Land, Water, and Mineral Resources, Campbell County, Wyoming. Wyoming State Geological Survey, County Resource Series No. 3.

Brinson, M. M., B. L. Swift, R. C. Plantico, and J. S. Barclay. 1981. Riparian Ecosystems: Their Ecology and Status. FWS/OBS-81/17. U.S. Fish and Wildlife Service, Biological Service Program, Washington, DC. 151 pages.

Brown, J. L. 1993. Sedimentology and Depositional History of the Lower Paleocene Tullock Member of the Fort Union Formation, Powder River Basin, Wyoming and Montana. U.S. Geological Survey Bulletin 1917–L. 42 pages.

Browne, R. 2001. Personal communication [*December 10* letter to K. Mullins, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Price of electricity of bulk power operation]. Division Engineer, Powder River Energy Corporation, Sheridan, Wyoming. 2 pages.

Bryson, C. 2001. Personal communication. [*May 23* telephone conversation with K. Cloutier, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Information on Campbell County planning and zoning]. County Planner, Campbell County Planning Department, Gillette, Wyoming.

Buffalo Chamber of Commerce. 2001. [*June 20* telephone conversation with K. Mullins, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Cost of housing in Buffalo]. Chamber of Commerce – Buffalo (Dee), Buffalo, Wyoming.

Bureau of Transportation Statistics. 2002. National Transportation Statistics 2000. Natural Gas Pipeline Profile. [Web Page]. Located at http://www.bts.gov/btsprod/nts/AppA_web/NATGASR.htm. Accessed August 7, 2002.

Burt, W. H. and R. P. Grossenheider. A Field Guide to Mammals of North America. Houghton Mifflin Company, New York, New York.

Busch, D.E. and M.L. Scott. 1995. Western riparian ecosystems. Pages 286–290 *in* LaRoe, E. T., et al., editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, Washington, DC.

Busch, D. E., N. L. Ingraham, and S. D. Smith. 1992. Water uptake in woody riparian phreatophytes of the southwestern United States: A stable isotope study. Ecological Applications 2: 450-459.Bradshaw, B. 1996. Powder River Basin Management Plan. Wyoming Game and Fish Department, Sheridan, Wyoming.

Buskirk, S. W., and R. A. Powell. 1994. Habitat ecology of fishers and American martens. *in* S. W. Buskirk, A. S. Harestad, and M. G. Raphael, editors. Martens, Sables, and Fishers: Biology and Conservation. Cornell University Press, Ithaca, New York.

Campbell County Chamber of Commerce. 2001. Housing Statistics [Web Page]. Located at http://www.gilletewyoming.net/pages/lifestyles/housing.htm. Accessed: June 6, 2001.

Campbell County Economic Development Corporation. 2001. Campbell County housing needs assessment by Pederson Planning Consultants and additional materials. May 15, 2001

Campbell County. 2000a. Campbell County Zoning District Map. Campbell County Engineers Office, Department of Public Works, Gillette, Wyoming.

Campbell County. 2000b. Campbell County Zoning Regulations, adopted 1969, revised August 1, 2000. Gillette, Wyoming.

Campbell County Sheriff's Department. 2000. Crime Statistics [Web Page]. Located at www.ccedc.net/pages/Gillette%20Wyoming%20pages/crime_states.html. Accessed: July 11, 2002.

Cam-Plex. 2001. Cam-Plex Multi-Event Facilities Home Page [Web Page]. Located at http://www.cam-plex.com/site/. Accessed: September 23, 2001.

Carter, M. F. 1998a. Northern Harrier. Pages 110–111 *in:* Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Carter, M. F. 1998b. Yellow-billed Cuckoo. Pages 204–205 *in:* Kingery, H. E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Carter, V. 1986. An overview of the hydrologic concerns related to wetlands in the United States. Canadian Journal of Botany 64: 364-374.

Case, J. C. 1997. Earthquakes and Active Faults in Wyoming. Wyoming State Geological Survey Preliminary Hazards Report 97–2. 58 pages.

BEST COPY AVAILABLE

Case, J. C. 2001. Wyoming Landslide Classification Scheme [Web Page]. Wyoming State Geological Survey. Located at http://wrds.uwyo.edu/wrds/wsgs/hazards/landslides/classscheme.html. Accessed: August 22, 2001.

Case, J. C., T. V. Edgar, and R. H. De Bruin. 2000. Subsidence Potential Related to Water Withdrawal in the Powder River Basin. Wyoming State Geological Survey, Wyoming Geo-notes Number 68 (pre-release version). 12 pages.

Cerovski, A. O., editor. 2000. Threatened, Endangered, and Nongame Bird and Mammal Investigations; Annual Completion Report. Wyoming Game and Fish Department, Nongame Program, Cheyenne, Wyoming.

Cerovski, A., M. Gorges, T. Byer, K. Duffy, and D. Felley, eds. 2001. Wyoming Bird Conservation Plan, Version 1.0. Wyoming Partners in Flight. Wyoming Game and Fish Department, Lander, Wyoming.

Chapman, P. M., Bailey, H., and E. Canaria. 2000. Toxicity of total dissolved solids associated with two mine effluents to chironomid larvae and early life stage of rainbow trout. Environ. Toxicol. Chem. 19: 210–214.

Chase, D. 2002. Personal Communication [*August 28* telephone conversation with K. Mullins, Greystone Environmental Consultants, RE: Capital, Operation and Reclamation Costs of Non-CBM Wells in the PRB]. Petroleum Engineer for the BLM Reservoir Management Group, Casper, Wyoming. 1 Page.

Christensen, R. 2002. Personal Communication [*July 31* facsimile to C. Florian, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Summary Report of Coal Permit Totals to Date; Active Coal Mine Permits, Powder River Basin, 1999-2001]. Wyoming Department of Environmental Quality (WDEQ), Land Quality Division, Cheyenne, Wyoming.

City of Gillette and Campbell County Planning Commissions. 1994. City of Gillette/Campbell County Comprehensive Planning Program, and Gillette Land Use Plan Map, City of Gillette and Campbell County Planning Commissions, June 1978, updated March 1994, Gillette, Wyoming.

City of Gillette. 1992. City of Gillette Zoning Ordinance, Ordinance No. 979, September 1992, Gillette, Wyoming.

City of Sheridan. 2000. City of Sheridan Zoning Ordinance. Adopted 1995, amended April 4, 2000, Sheridan, Wyoming.

Clark, T. W., A. H. Harvey, R. D. Dorn, D. L. Genter, and C. Groves, editors. 1989. Rare, Sensitive, and Threatened Species of the Greater Yellowstone Ecosystem. Northern Rockies Conservation Cooperative, Montana Natural Heritage Program, The Nature Conservancy, and Mountain West Environmental Services.

Clark, T. W., and M. R. Stromberg. 1987. Mammals in Wyoming. University of Kansas, Museum of Natural History.

Clark, T. W., T. M. Campbell, III, and T. N. Hauptman. 1989a. Demographic characteristics of American marten populations in Jackson Hole, Wyoming. Great Basin Naturalist 49:587–596.

Clark, T. W., A. H. Harvey, R. D. Dorn, D. L. Genter, and C. Groves, (eds). 1989b. Rare, Sensitive, and Threatened Species of the Greater Yellowstone Ecosystem. Northern Rockies Conservation Cooperative, Montana Natural Heritage Program. The Nature Conservancy, and Mountain West Environmental Services.

Clark, M. L., K. A. Miller, and M. H. Brooks. 2001. U.S. Geological Survey Monitoring of Powder River Basin Stream – Water Quantity and Quality. U.S. Geological Survey Water-Resources Investigations Report 01-4279, 7 pages.

Clements, W. H. 1999. Metal tolerance and predator-prey interactions in benthic macroinvertebrate stream communities. Ecol. Appl. 9: 1073-1084.

Coates, D. A. 1991. Clinker. Page 448 *in* Geological Society of America. Quaternary Nonglacial Geology: Conterminous U.S. Geological Society of America, The Geology of North America, Decade of North American Geology, Vol. K–2.

Coates, D. A., and E. L. Heffern. 1999. Origin and Geomorphology of Clinker in the Powder River Basin, Wyoming and Montana. Pages 211–229 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Cole, E. K., M. D. Pope, and R. G. Anthony. 1997. Effects of road management on movement and survival of Roosevelt elk. Journal of Wildlife Management 61:1115-1126.

Colorado Natural Areas Program. 1998. Native Plant Revegetation Guide for Colorado. Volume III. Colorado Natural Areas Program, Denver, Colorado.

Colorado Oil and Gas Conservation Commission. 2000. Summary Report of Bradenhead Testing, Gas Well Remediation, and Ground Water Investigations, San Juan Basin, La Plata County, Colorado. Colorado Oil and Gas Conservation Commission unpublished report. May 26.

Connelly, J. W., H. W. Browers, and R. J. Gates. 1988. Seasonal movement of sage grouse in southeastern Idaho. Journal of Wildlife Management: 52: 116–122.

Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28(4): 967-985.

Converse County. 1978. Converse County Land Use Plan. Converse County, Douglas, Wyoming.

438

BEST COPY AVAILABLE

Cooperative Agricultural Pest Survey. 1999. University of Wyoming College of Agriculture CAPS website: http://w3.uwyo.edu/~caps/caps.html. Data compiled July 1999.

Council on Environmental Quality. 1981. Forty most asked questions concerning CEQ's National Environmental Policy Act regulations (40 CFR 1500–1508). Federal Register 46(55):18026–18038.

Courtney, L. A. and W. H. Clements. 2000. Sensitivity to acidic pH in benthic invertebrate assemblages with different histories of exposure to metals. Journal of the North American Benthological Society 19(1): 112–137.

Cowardin, L. M., M. V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service Publication FWS/OBS-79/31. Washington, DC. 103 pages.

Craig, Jr., G. S., and J. G. Rankl. 1978. Analysis of Runoff from Small Drainage Basins in Wyoming. U.S. Geological Survey Water Supply Paper 2056. 70 pages.

Crockett, F. 2001. Personal communication [*September 19* facsimile to D. Cameron, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Average BOE and percentage of oil and gas wells]. U.S., Bureau of Land Management, Buffalo, Wyoming.

Crockett, F., M. Ellis, A. Ochs, G. Stricker, G. Gunther, and R. Flores. 2001. An estimate of coal gas resources in the Powder River Basin, Wyoming. Paper delivered at the WGA Conference in Casper, Wyoming, on October 10, 2001.

Culbertson W. C., and W. J. Mapel. 1976. Coal in the Wasatch Formation, northwest part of the Powder River Basin near Sheridan, Sheridan County, Wyoming. Pages 193–201 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Curry, D.L. 1976. Evaluation of uranium resources in the Powder River Basin, Wyoming. Pages 235–242 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Daddow, P.B. 1986. Potentiometric-Surface map of the Wyodak-Anderson Coal Bed, Powder River Structural Basin, Wyoming, 1973–1984. U.S. Geological Survey Water-Resources Investigations Report 85–4305.

Dahl, A.R. and J.L. Hagmaier. 1976. Genesis and characteristics of the Southern Powder River Basin uranium deposits, Wyoming. Pages 243–252 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Davis, R.W. 1976. Hydrologic factors related to coal development in the eastern Powder River Basin. Geological Association 28th Annual Field Conference Guidebook. Pages 203–207 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Davison, M. 2001a. Personal communication [*May 25* e-mail to S. Barker, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Powder River Basin EIS]. Wyoming Department of Environmental Quality, Cheyenne, Wyoming.

Davison, M. 2001b. Personal communication. [*May 25* e-mail to S. Barker, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* NPDES Outfall Locations Database]. Wyoming Department of Environmental Quality, Cheyenne, Wyoming. 2 pages.

Day, M. 2000. Personal communication. [*Undated* documentation of conversation with J. Meyer, BLM, Casper, Wyoming *RE* infiltration and evaporation of CBM produced water from a reservoir site.] Applied Hydrology and Associates, Inc. Denver, Colorado. Five pages.

De Bruin, R.H., and R.M. Lyman. 1999. Coalbed methane in Wyoming. Pages 61–72 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

De Bruin, R.H., R.M. Lyman, R.W. Jones, and L.W. Cook. 2001. Coalbed Methane in Wyoming. Wyoming State Geological Survey Information Pamphlet No. 7 (revised). 19 pages.

Deibert, P. 2002. Personal communication [*August 15* with M. Schweich, Greystone Environmental Consultants regarding the petitions to list the greater sage grouse]. Biologist with the U.S. Fish and Wildlife Service in Cheyenne, Wyoming.

Delong, A.K., J.A. Crawford, and D.C. Delong Jr. 1995. Relationships between vegetational structure and predation of artificial sage grouse nests. Journal of Wildlife Management 59(1): 88-92.

Delson, E., 1971. Fossil Mammals of the early Wasatchian Powder River Local Fauna, Eocene of northeastern Wyoming. Bulletin of the American Museum of Natural History:146:307–364.

Department of Land and Water Conservation (DLWC). 2000. Section 2: all about salinity. Pages 10-22 in Taking on the Challenge: NSW Salinity Strategy. ISBN 0 7347 5146 X. New South Wales Department of Land and Water Conservation, Australia. August. Located at http://www.dlwc.nsw.gov.au/care/salinity/index.html#Stategy. Accessed July 24, 2002.

Deromodi, J. 1996. North Platte River - Pine Ridge to Nebraska Basin Management Plan. Wyoming Game and Fish Department. Lander, Wyoming.Devine, J.F.

2002. Review of Draft Environmental Impact Statement and Draft Planning Amendment (DPA) for the Powder River Basin Oil and Gas Projects. Comments from the U.S. Geological Survey. March 22.

Dinsmore, J.J. 1983. Mountain plover (*Charadrius montanus*). Pages 185–196 *in* J. S. Armbruster, editor. Impacts of Coal Surface Mining on 25 Migratory Bird Species of High Federal Interest. U.S. Fish and Wildlife Service FWS/OBS–83/35. 348 pages.

Dorn, J.L. and R.D. Dorn. 1990. Wyoming Birds. Mountain West Publishing, Cheyenne, Wyoming.

Dorn, Robert D. 1992. Vascular Plants of Wyoming. Second Edition. Mountain West Publishing; Cheyenne, WY.Devine, J.F. 2002. Review of Draft Environmental Impact Statement and Draft Planning Amendment (DPA) for the Powder River Basin Oil and Gas Project. Memorandum from James F. Devine of the U.S. Geological Survey. May 15, 2002.

Downey, J.S. 1986. Geohydrology of Bedrock Aquifers in the Northern Great Plains in Parts of Montana, North Dakota, South Dakota, and Wyoming. U.S. Geological Survey Professional Paper 1402-E, 87 pages.

Dugan, J.T., R.D. Hobbs, and L.A. Ihm. 1990. Hydrologic Characteristics of Soils in the High Plains, Northern Great Plains, and Central Texas Carbonates Regional Aquifer Systems. U.S. Geological Survey Hydrologic Investigations Atlas HA–714.

Edgar, T.V., and J.C. Case. 2000. Pumping Induced Settlement of Aquifers. Wyoming State Geological Survey Preliminary Hazards Report PHR 00–1. 10 pages.

Edge, W.D. and C.L. Marcum. 1985. Movement of elk in response to logging disturbances. Journal of Wildlife Management 49(4): 926-930.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The Birder's Handbook: A Field Guide to the Natural History of North American Birds. Simon and Schuster, New York.

Ellis, M.S. 1999. U.S. Geological Survey 1999 Assessment of Wyodak-Anderson coal resources in the Powder River Basin, Wyoming, and Montana. Pages 43–60 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Ellis, M.S. and R.B. Colton. 1994. Geologic Map of the Powder River Basin and Surrounding Area, Wyoming, Montana, South Dakota, North Dakota, and Nebraska. U.S. Geological Survey Miscellaneous Investigations Map I-2298.

Ellis, M.S., C.L. Molnia, L.M. Osmonson, A.M. Ochs, T.J. Rohrbacher, T. Mercier, and L.N.R. Roberts. 2002. Evaluation of Economically Extractable

Coal Resources in the Gillette Coal Field, Powder River, Basin, Wyoming. U.S. Geological Survey Open-File Report 02-180.

Energy Information Administration. 2002a. Annual Energy Outlook 2002 with Projections to 2020, Table 14 Natural Gas Prices, Margins and Revenues. [Web Page]. Located at http://www.eia.doe.gov/oiaf/aeo/aeotab_14.htm. Accessed: August 28, 2002.

Energy Information Administration. 2002b. Annual Energy Outlook 2002 with Projections to 2020, Table 15. Oil and Gas Supply. [Web Page]. Located at http://www.eia.doe.gov/oiaf/aeo/aeotab_15.htm. Accessed: September 4, 2002.

Energy Laboratories. 2001a. Water Quality Analyses from the Powder River Basin, Wyoming. Unpublished Laboratory Reports. Energy Laboratories, Gillette, Wyoming.

Energy Laboratories. 2001b. Unpublished confidential data on CBM produced water quality. Energy Laboratories, Gillette, Wyoming. Four compact discs.

Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young Jr., K.J. Semka, and R.E. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. Western EcoSystems Technology, Inc. Cheyenne, Wyoming.

Fausch, K.D., and R.G. Bramblett. 1991. Disturbance and fish communities in intermittent tributaries of a Western Great Plains River. Copeia 3: 659-674.

Federal Highway Administration (FHWA) 1978. FHWA Highway Traffic Noise Prediction Model. Report Number FHWA-RD-77-108, Washington, D.C.

Fertig, W., and G. Beauvais. 1999. Wyoming Plant and Animal Species of Special Concern. Unpublished report. Wyoming Natural Diversity Database, Laramie, Wyoming.

Fertig, W. 2000a. *Spiranthes diluvialis*. Ute Ladies' Tresses. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Fertig, W. 2000b. Status review of the Ute ladies'-tresses (*Spiranthes diluvialis*) in Wyoming. Wyoming Natural Heritage Diversity Database. Univ. of Wyoming. Laramie, Wyoming. 17 pages.

Fertig, W. 2000c. *Aquilegia laramensis*. Laramie Columbine. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

BEST COPY AVAILABLE

Fertig, W. 2000d. *Artemisia porteri*. Porter's Sagebrush. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Fertig, W. 2000e. *Astragalus nelsonianus*. Nelson's Milkvetch. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Fertig, W. 2000f. *Cleome multicaulis*. Many-stemmed Spider-flower. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Fertig, W. 2000g. *Cymopterus williamsii*. William's Wafer Parsnip. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Fertig, W. 2000h. *Penstemon caryi*. Cary Bearttongue. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Fertig, W. 2000i. *Sphaeromeria simplex*. Laramie False Sagebrush. Wyoming Natural Diversity Database State Species Abstract. Located at http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm. Accessed: July 31, 2002.

Findlay, C.S. and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14(1):86-94.

Fitzgerald, J.P., C.A. Meaney, and D.M. Armstrong. 1994. Mammals of Colorado. Denver Museum of Natural History, Denver, Colorado.

Flores, R.M. 1999. Wyodak-Anderson coal zone in the Powder River Basin, Wyoming and Montana: A tale of uncorrelatable coal beds. Pages 1–24 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Flores, R. M., A.M. Ochs, L.R. Bader, R.C. Johnson, and D. Vogler. 1999. Framework geology of the Fort Union Coal in the Powder River Basin, Wyoming, and Montana. Chapter PF, pages 1–40 *in* Fort Union Coal Assessment Team. 1999 Resource Assessment of Selected Tertiary Coal Beds and Zones in the Northern Rocky Mountains and Great Plains Region. U.S. Geological Survey Professional Paper 1625–A.

Flores, R.M., and L.R. Bader. 1999. Fort Union Coal in the Powder River Basin, Wyoming and Montana: A synthesis. Chapter PS, pages 1–75, *in* Fort Union Coal Assessment Team. 1999 Resource Assessment of Selected Tertiary

Coal Beds and Zones in the Northern Rocky Mountains and Great Plains Region. U.S. Geological Survey Professional Paper 1625–A.

Flores, R.M., G.D. Stricker, J.F. Meyer, T. Doll, P.H. Norton, Jr., R.J. Livingston, and M.C. Jennings. 2001. A Field Conference on Impacts of Coalbed Methane Development in the Powder River Basin, Wyoming. Impacts and Issues of CBM Development. U.S. Geological Survey Open-File Report 01–126. 26 pages.

Fox, Douglas G.; Bartuska, Ann M.; Byrne, James G; and others. 1989. A Screening Procedure to Evaluate Air Pollution Effects on Class I Wilderness Areas. Gen. Tech. Rep. RM-168. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Ganskopp, David C., 1986. Tolerances of Sagebrush, Rabbitbrush, and Greasewood to Elevated Water Tables. Journal of Range Management 39(4):334-337

Garber, C.S. 1994. A Status Survey for Spotted Frogs (*Rana pretiosa*), Wood Frogs (*Rana sylvatica*) and Boreal Toads (*Bufo boreas*) in the Mountains of Southern and Eastern Wyoming. Unpublished report. Wyoming Natural Diversity Database, Laramie, Wyoming.

Geist, V.A. 1978. Behavior. Pages 283-296 *in:* J.L. Schmidt and D.L. Gilbert, eds. Big game of North America: ecology and management. Stackpole Books. Harrisburg, Pennsylvania.

George, Gene R. 2001. Testimony of Gene R. George, WPG#8 Petroleum Association of Wyoming, Before The Subcommittee on Energy and Mineral Resources of the Committee on resources of the House of Representatives Regarding Orderly Development of Coalbed Methane Resources from Public Lands. Longworth House Office Building. Washington, D.C. Thursday, September 6, 2001.

Gerard, L. 1999. Personal communication. Wildlife Biologist, U.S. Bureau of Land Management, Buffalo, Wyoming.

Gerritsen, J. Carlson, R.E., Donald, L.D., Faulkner, C., Gibson, G.R., Harcum, J., and S. A. Markowitz. 1998. Lake and Reservoir Bioassessment and Biocriteria Technical Guidance Document. EPA 841-B-98-007. U.S. Environmental Protection Agency. Office of Water, Washington, D.C.

Gibbs, J.P. 2000. Wetland loss and biodiversity conservation. Conservation Biology 14(1):314-317.

Gilmer, D.S. and R.E. Stewart. 1983. Ferruginous hawk populations and habitat use in North Dakota. Journal of Wildlife Management 47:146-157.

Glass, G. B. 1997. Coal Geology of Wyoming. Wyoming State Geological Survey Reprint (Keystone Coal Industry Manual) No. 63. 21 pages.

444

Glass, G.B., and D.L. Blackstone, Jr. 1996. Geology of Wyoming. Wyoming State Geological Survey Information Pamphlet No. 2. 12 pages.

Glass, G. B., R. W. Jones, and R. H. De Bruin. 1987. Investigation of the Potential for Near-Surface Explosive Concentrations of Methane to Occur in the Rawhide Village Subdivision, Campbell County, Wyoming. Unpublished report. Wyoming State Geological Survey Report for the Wyoming Department of Environmental Quality. 7 pages plus 3 plates.

Glinski, R.L., 1998. Golden Eagle. Pages 112-114 *in:* R.L. Glinski, ed. The Raptors of Arizona. The University of Arizona Press, Tucson.

Good, R.E., D.P. Young, and J. Eddy. 2002. Draft Report. Distribution of Mountain Plovers in the Powder River Basin, Wyoming. Solicitation No. KAQ001005. Western EcoSystems Technology, Inc (WEST), Cheyenne, Wyoming. Prepared for BLM, Cheyenne, Wyoming.

Goodfellow, W.L., Ausley, L.W., Burton, D.T., Denton, D.L., Dorn, P.B., Grothe, D.R., Heber, M.A., Norberg-King, T.J., and J.H. Rodgers, Jr. 2000. Major ion toxicity in effluents: a review with permitting recommendations. Environ. Toxicol. Chem. 19: 175-182.

Goolsby, J. E., and A. K. Finley. 2000. Correlation of Fort Union Coals in the Powder River Basin, Wyoming: A proposed new concept. Pages 51–74 *in* Classical Wyoming Geology in the New Millenium: Wyoming Geological Association 51st Field Conference Guidebook.

Gore, J.A. 1987. Development and application of macroinvertebrate instream flow models for regulated flow management. Pages 99-115. In: J.F. Craig and J.B. Kemper (eds.) Regulated Streams: Advances in Ecology. Plenum Press, New York.

Gorody, A.W. 1999. The Origin of Natural Gas in the Tertiary Coal Seams on the Eastern Margin of the Powder River Basin. Pages 89-101 *in* W.R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin, Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Gregg, M.A, J.A. Crawford, M.S. Drut, and A.K. Delong. 1994. Vegetational cover and predation of sage grouse nests in Oregon. Journal of Wildlife Management 58(1): 162-166.

Gresswell, R.E. 1995. Yellowstone cutthroat trout. Pages 36–54 *in:* M.K. Young, technical editor. Conservation Assessment for Inland Cutthroat Trout. U.S. Forest Service General Technical Report RM–GTR–256.

Greystone Environmental Consultants and ALL Consulting. 2002. Working Draft: Technical Report, Surface Water Modeling of Water Quality Impacts Associated with Coal Bed Methane Development in the Powder River Basin. Prepared in support of the U.S. Bureau of Land Management, Buffalo Field Office, and Billings Field Office. Unpublished report.

445

Griswold, M. 2002. Campbell County Weed and Pest Control District. Personal communication with Janelle Gonzales, BLM – Buffalo field Office. August 8.

Gross, N. 2001. Personal communication [*August 20* with K. Mullins, Greystone, Greenwood Village, Colorado. *RE:* the local economy]. Executive director, Buffalo Chamber of Commerce, Buffalo, Wyoming.

Hammerson, G. 1999. Amphibians and Reptiles in Colorado. University Press of Colorado. Niwot, Colorado.

Hanson, B.R., S.R. Grattan, and A. Fulton. 1999. Agricultural Salinity and Drainage. Division and Agriculture and Natural Resources Publication 3375. University of California, Davis, California. 160 pages.

Harris, R.E., W.D. Hausel, and J.E. Meyer. 1985. Metallic and Industrial Minerals Map of Wyoming. Wyoming State Geological Survey, Map Series 14.

Harris, C. M. 1991. Handbook of Acoustical Measurements and Noise Control, McGraw-Hill, Inc., New York, New York. 345 pages.

Harris, R. E., and J. K. King. 1989. Industrial Minerals and Construction Materials Map of the Powder River Basin and Adjacent Uplifts, Wyoming. Wyoming State Geological Survey. Map Series 30.

Hart, B.T., P. Bailey, R. Edwards, K. Hortle, K. James, and A. McMahon. 1991. A review of the salt sensitivity of the Australian freshwater biota. Hydrobiologia 210: 105-144.

Heffern, E.L., and D.A. Coates. 1997. Clinker — Its occurrence, uses, and effects on coal mining in the Powder River Basin. Pages 151–166 *in* R.W. Jones and R.E. Harris, editors. Proceedings of the 32nd Annual Forum on the Geology of Industrial Minerals. Wyoming State Geological Survey Public Information Circular 38.

Heffern, E.L., and D.A. Coates. 1999. Hydrogeology and ecology of clinker in the Powder River Basin, Wyoming and Montana. Pages 231–252 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Hergert, G., and Knudsen, D. 1997. Irrigation Water Quality Criteria. Published by Cooperative Extension of Agriculture and Natural Resources, University of Nebraska – Lincoln. [Website] Located at: http://www.ianr.unl.edu/pubs/water/g328.htm. Accessed August 28, 2002.

Hickey, D.A., and T. McNeilly. 1975. Competition between metal tolerant and normal plant populations; a field experiment on normal soil. Evolution 29:458-464

Hobbs, N.T. 1989. Linking energy balance to survival in mule deer: development and test of a simulation model. Wildlife Monographs 101: 1-39.

446

BEST COPY AVAILABLE

Hobbs, R.J., and L.F. Huenneke. 1992. Disturbance, diversity, and invasion: implications for conservation. Conservation Biology 6(3): 324-337.

Hodson, W.G., R.H. Pearl, and S.A. Druse. 1973. Water Resources of the Powder River Basin and Adjacent Areas, Northeastern Wyoming. U.S. Geological Survey Hydrologic Investigations Atlas HA–465. 4 sheets.

Hoffer, R. 2002. Personal Communication [*July 31* telephone conversation with K. Mullins, Greystone Environmental Consultants *RE:* Location of Hutterite colonies and Hutterite Populations]. King Colony Spokesperson, Lewiston, Montana.

Hoffman, R.W. (ed.). 2001. Northwest Colorado Columbian sharp-tailed grouse conservation plan. Northwest Colorado Columbian Sharp-tailed Grouse Work Group and Colorado Division of Wildlife. Fort Collins, Colorado.

Horpestad, A. 2001. Water Quality Analysis of the Effects of CBM Produced Water on Soils, Crop Yields and Aquatic Life. Montana Department of Environmental Quality. [Website] Located at: http://www.deq.state.mt.us/CoalBedMethane/Criteria-sar-EC-h.htm. Accessed August 27, 2002.

Hotchkiss, W.R., and J.F. Levings. 1986. Hydrogeology and Simulation of Water Flow in Strata above the Bearpaw Shale and Eqivalents of Eastern Montana and Northeastern Wyoming. U.S. Geological Survey Water-Resources Investigations Report 85–4281. 72 pages.

Hubert, W.S. 1993. The Powder River: a relatively pristine stream on the Great Plains. Pages. 387-395 *in*: Proceeding of the Symposium on Restoration Planning for the Rivers of the Mississippi River Ecosystem (Hesse, L.W., C.B. Stalnaker, N.G. Benson, and J.R. Zuboy, Technical Editors). Biology Report 19. U.S. Dept. of the Interior, National Biological Survey, Washington, D.C.

Hydro-Engineering. 1996. GAGMO 15-year Report. Prepared for the Gillette Area Groundwater Monitoring Organization, Gillette, WY.

Hydro-Engineering. 2000. GAGMO Annual Report for 1999. Prepared for the Gillette Area Groundwater Monitoring Organization, Gillette, WY.

Hydrologic Consultants, Inc. 2001. Hydrologic and Geochemical Assessment, Wild Horse Creek, Campbell and Sheridan Counties, Wyoming. Unpublished report.

Ingelfinger, F.M. 2001. The effects of natural gas development on sagebrush steppe passerines in Sublette County, Wyoming. M.S. Thesis, University of Wyoming, Laramie.

James, K.R. and Hart, B.T. 1993. Effects of salinity on four freshwater macrophytes. Australian Journal of Marine & Freshwater Research. 44(5): 769-777.

BEST COPY AVAILABLE

Johnsgard, P.A. 1986. Birds of the Rocky Mountains. Colorado Association University Press. Boulder, Colorado. 504 pages.

Johnson, R.R. and J.F. McCormick (technical coordinators). 1979. Symposium Proceedings: Strategies for the Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Callaway Gardens, Georgia. December 11-13, 1978. U.S. Forest Service General Technical Report WO-12, Washington, DC. 410 pages.

Jones, A.G. 1984. Typification of *Aster jessicae* Piper and reinstatement of *A. mollis* Rydberg (Asteraceae). Madrono 31(2):113–122.

Jones, C., R.S. Hoffman, D.W. Rice, M.D. Engstrom, R.D. Bradley, D.J. Schmidly, C.A. Jones, and R.J. Baker. 1997. Revised Checklist of North American Mammals North of Mexico, 1997. Occasional Papers, Museum of Texas Tech University, Number 173.

Jones, J. 2001. Summary of Proposed Drilling Program for the Companies' 12-Area Project Area. Western Gas Resources, Inc., Denver, Colorado. 16 pages.

Jones, R.W., R.H. De Bruin, and G.B. Glass. 1987. Investigations of Venting Methane and Hydrogen Sulfide Gas at Rawhide Village, Campbell County, Wyoming. *in* Wyoming Department of Environmental Quality. Rawhide II Project Report, Appendix I, Geology. Unpublished report. Wyoming Department of Environmental Quality, Cheyenne, Wyoming. 23 pages plus 12 plates.

Jones, S. 1998a. Burrowing Owl. Pages 220-221 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Jones, S. 1998b. Olive-sided Flycatcher. Pages 268-269 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Jones, S.R. 1998c. Prairie Falcon. Pages 130-131 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Jones, C., R.S. Hoffmann, D.W. Rice, R.J. Baker, M.D. Engstrom, R.D. Bradley, D.J. Schmidly, and C.A. Jones. 1997. Revised checklist of North American mammals north of Mexico, 1997. Occasional Papers, Museum of Texas Tech University, Number 173. Located on the Internet at: http://www.nsrl.ttu.edu/pubs/opapers/op173.htm. Accessed July 25, 2002.

Kauffman, J.B. and W.C. Kreuger. 1984. Livestock impacts on riparian ecosystems and streamside management implications—a review. Journal of Range Management 37: 430-437.

448

BEST COPY AVAILABLE

Keanini, D. 2001a. Personal communication [*September 20* e-mail to K. Mullins, Greystone, Greenwood Village, Colorado. *RE:* Employment needs and personnel required for PA]. Western Gas Resources, Inc., Denver, Colorado.

Keanini, D. 2001b. Personal communication [*December 11* written communication with K. Mullins, Greystone, Greenwood Village, Colorado. *RE*: Gas vs. Electric Costs]. Vice President of Engineering, Environment, and Safety, Western Gas, Denver, Colorado. 2 pages.

Keefer, W. R. 1974. Regional Topography, Physiography, and Geology of the Northern Great Plains. U.S. Geological Survey Open-File Report 74–50. 18 pages and 4 sheets.

Keinath, D., and J. Bennet. 2000. Distribution and Status of the Boreal Toad (*Bufo boreas boreas*) in Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming.

Kingery, H. E, editor. 1998. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership, Denver, Colorado.

Knick, S.T., and J.T. Rotenberry. 1995. Landscape characteristics of fragmented shrub steppe habitats and breeding passerine birds. Conservation Biology 9(5): 1059-1071.

Knight, Dennis H. 1994. Mountains and Plains: The Ecology of Wyoming Landscapes. Yale University.

Kolin, M. 2001. Personal communication [*December 10* written communication with K. Mullins, Greystone, Greenwood Village, Colorado. *RE*: Water handling cost associated with conceptual Project Designs]. Professional Engineer, Greystone, Greenwood Village, Colorado. 5 pages.

Kolin, M. 2002. Unpublished Data: Preliminary Engineering Cost Estimates on Water Handling Facilities. Greystone, Greenwood Village, Colorado. 3 Pages.

Kuhn, G., 2002. Analysis of Discharge and Water-Quality Data for Selected Stations in and Adjacent to the Powder River Basin. Unpublished Document. U.S. Geological Survey. Denver, Colorado.

Lageson, D.R., A.J. Ver Ploeg, G.B. Glass, W.D. Hausel, R.M. Breckenridge, D.R. Gaylord, R.W. Marrs, J.K. King, and A.L. Madina. 1978. Sheridan County, Wyoming. Wyoming State Geological Survey, County Resource Series No. 5.

Lageson, D.R., and D.R. Spearing. 1991. Roadside Geology of Wyoming. Second edition. Mountain Press Publishing Company, Missoula, Montana. 271 pages.

449

Lane, D.W., F.K. Root, and G.B. Glass. 1972. Converse County, Wyoming; Geologic Map Atlas and Summary of Economic Mineral Resources. Wyoming State Geological Survey, County Resource Series No. 1.

Langhus, B. Personal communication. [*August 23* e-mail to S. Barker, Greystone Environmental Consultants, Greenwood Village, Colorado *RE:* CX Ranch Discharge.] ALL Consultants, Inc. Tulsa, Oklahoma.

Laudon, R.B., editor. 1976. Geology and Energy Resources of the Powder River. Wyoming Geological Association Guidebook, 28th Annual Field Conference. 328 pages.

Lemly, A.D., and G.J. Smith. 1987. Aquatic Cycling of Selenium: Implications for Fish and Wildlife. U.S. Fish and Wildlife Service. Fish and Wildlife Leaflet 12. Washington, D.C. 10 pages.

Lenfest, L.W., Jr. 1987. Recharge of Shallow Aquifers through Two Ephemeral Stream Channels in Northeastern Wyoming, 1982–1983. U.S. Geological Survey Water-Resources Investigations Report 85–4311.

Leonard, S., G. Staidl, J. Fogg, K. Gebhardt, W. Hagenbuck, and D. Prichard. 1992. Procedures for Ecological Site Inventory — with Special Reference to Riparian — Wetland Sites (draft). U.S. Bureau of Land Management, Service Center Report TR 1737–7.

Levad, R. 1998. Purple Martin. Pages 334-335 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Lewis, S. 2002. Converse County Weed and Pest Control District. Personal communication with Janelle Gonzales, BLM – Buffalo field Office. August.

Lewis, B.D., and W.R. Hotchkiss. 1981. Thickness, Percent Sand, and Configuration of Shallow Hydrogeologic Units in the Powder River Basin, Montana and Wyoming. U.S. Geological Survey Miscellaneous Investigations Map I–1317.

Likwartz, D.J. 2001. Personal communication [*April 26* notice. *RE*: Coalbed methane water production rate dropped significantly last year]. State Oil and Gas Supervisor, Wyoming Oil and Gas Conservation Commission, Casper, Wyoming. 3 pages.

Lindner-Lunsford, J.B., C. Parrett, J.F. Wilson, Jr., and C.A. Eddy-Miller. 1992. Chemical Quality of Surface Water and Mathematical Simulation of the Surface-Water System, Powder River Drainage Basin, Northeastern Wyoming and Southeastern Montana. U.S. Geological Survey Water-Resources Investigations Report 91–4199. 85 pages.

Litzel, Rod. 2002. Johnson County Weed and Pest Control District. Personal communication with Janelle Gonzales, BLM Buffalo Field Office. August 1.

450

BEST COPY AVAILABLE

Long, M.M. 2000. Personal Communication [*June 5* memorandum to Mr. D. Stenger, Bureau of Land Management, Buffalo Field Office, Buffalo, Wyoming. RE: Proposed EIS for additional coal bed methane applications for permits to drill in the Buffalo Resource Management Plan area]. 7 pages.

Love, J.D., A.C. Christiansen, and L.W. McGrew. 1987. Geologic Map of the Newcastle 1° x 2° Quadrangle, Northeastern Wyoming and Western South Dakota. Wyoming State Geological Survey Map Series 25–I.

Lovejoy, T.E, B.O. Bierregaard, Jr., A.B. Rylands, J.R. Malcolm, C.E. Quintela, L.H. Harper, K.S. Brown, Jr., A.H. Powell, G.V.N. Powell, H.O.R. Schubart, and M.B. Hays. 1986. Habitat fragmentation in the temperate zone. Pages 257-285 *in:* M.E. Soule, ed. Conservation Biology. The Science of Scarcity and Diversity. Sinauer Associates. Sunderland, Massachusetts.

Lohman, S.W. 1972. Ground-Water Hydraulics. U.S. Geological Survey Professional Paper 708, 70 pages.

Lowham, H. W. 1988. Streamflows in Wyoming. U.S. Geological Survey Water-Resources Investigations Report 88–4045. 78 pages.

Lowry, M.E. and R.R. Cummings. 1966. Ground-Water Resources of Sheridan County, Wyoming. U.S. Geological Survey Water-Supply Paper 1807. 77 pages.

Lowry, M.E., J.F. Wilson, Jr., and others. 1986. Hydrology of Area 50, Northern Great Plains and Rocky Mountain Coal Provinces, Wyoming and Montana. U.S. Geological Survey Water-Resources Investigations Open-File Report 83–545. 137 pages.

Lowry, M.E., P.B. Daddow, and S.J. Rucker, IV. 1993. Assessment of the Hydrologic System and Hydrologic Effects of Uranium Exploration and Mining in the Southern Powder River Basin Uranium District and Adjacent Areas, Wyoming, 1983. U.S. Geological Survey Water-Resources Investigations Report 90–4154. 42 pages.

Lowry, M.E., and J.G. Rankl. 1987. Hydrology of the White Tail Butte Area, Northern Campbell County, Wyoming. U.S. Geological Survey, Water-Resources Investigations Report 82-4117.

Luce, B., A. Cerovski, B. Oakleaf, J. Priday, and L. Van Fleet. 1999. Atlas of Birds, Mammals, Reptiles, and Amphibians in Wyoming. Wyoming Game and Fish Department, Wildlife Division, Cheyenne, Wyoming.

Lyman, R. M., and J. E. Volkmer. 2001. Pyrophoricity (Spontaneous Combustion) of Powder River Basin Coals — Considerations for Coalbed Methane Development. Wyoming State Geological Survey Coal Report CR 01–1. 12 pages.

Lyon, L.J. 1979. Habitat effectiveness for elk as influenced by roads and cover. Journal of Forestry 77: 658-660.

Lyon, L.J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry 81: 592-595.

Lyon, A.G. 2000. The potential effects of natural gas development on sage grouse near Pinedale, Wyoming. M.S. Thesis, University of Wyoming, Laramie.

Macke, D. L. 1993. Cambrian through Mississippian Rocks of the Powder River Basin, Wyoming, Montana, and Adjacent Areas. U.S. Geological Survey Bulletin 1917–M. 174 pages.

Malm, W.C., et al. 2000. Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report III. Prepared fro IMPROVE by the USDI National Park Service and the Cooperative Institute for Research in the Atmosphere. Fort Collins, Colorado. Located at: http://vista.cira.colostate.edu/improve/Publications/Reports/2000/2000.htm.

Marinari, P. 2001. Personal communication [*August 22* telephone conversation with S. Faulk, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Black-footed ferret occurrence in Wyoming]. 1 page.

Martin, L.J., D.L. Naftz, H.W. Lowham, and J.G. Rankl. 1988. Cumulative Potential Hydrologic Impacts of Surface Coal Mining in the Eastern Powder River Structural Basin, Northeastern Wyoming. U.S. Geological Survey Water-Resources Investigations Report 88-4046. Prepared in Cooperation with the Wyoming Department of Environmental Quality and the U. S. Office of Surface Mining, Cheyenne, Wyoming.

McDowell, B. 1996a. Belle Fourche River Basin Management Plan (FXSN8BF). Wyoming Game and Fish Department. Sheridan, Wyoming.

McDowell, B. 1996b. Little Bighorn River Basin Management Plan (FXSN8LH). Wyoming Game and Fish Department. Sheridan, Wyoming.

McDowell, B. 1996c. Little Missouri River Basin Management Plan (FXSN8LM). Wyoming Game and Fish Department. Sheridan, Wyoming.

Meffe, G.K., and C.R. Carroll, eds. 1994. Principles of Conservation Biology. Sinauer Associates. Sunderland, Massachusetts.

Merrill, E.H., T.W. Kohley, M.E. Herdendorf, W.A. Reiners, K.L. Driese, R.W. Marrs, and S.H. Anderson. 1996. The Wyoming GAP Analysis Project Final Report. Available on the Internet at: http://www.wygisc.uwyo.edu/wbn/gap.html. Accessed July 31, 2002.

Meyer, J. 1999. General Draw-Down Map — Wyodak/Anderson Coal Bed, 1980 to 1998. Pages 87–88 *in:* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50^{th} Field Conference Guidebook.

Meyer, J. 2000. Belle Fourche River Basin 1993 to 1999. Memorandum to File, November 2, 2000. Bureau of Land Management, Casper, Wyoming.

457

BEST COPY AVAILABLE

Meyer, J. 2002a. Personal communication [*August 2* e-mail to S. Barker, Greystone Environmental Consultants, Greenwood Village, Colorado *RE*: Coal SAR – EC Map and Data] Physical Scientist, Bureau of Land Management, Casper, Wyoming. 4 pages.

Meyer, J. 2002b. Personal communication [*August 21* e-mail to S. Barker, Greystone, Greenwood Village, Colorado. *RE*: Determination of Powder River Basin, Wyoming Produced Water and Stream Water Quality and Quantity by Sub-Basin]. Physical Scientist, Bureau of Land Management, Casper, Wyoming. 4 pages.

Meyer, J. 2002c. Personal communication. [*October 7* e-mail to K. Wilkerson, Greystone Environmental Consultants, Greenwood Village, Colorado, *RE* Alluvial Impacts – Final.] Physical Scientist, Bureau of Land Management, Casper, Wyoming. 4 pages.

Milburn, B. 2001. Personal communication. [*September 4* telephone conversation with K. Cloutier, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE*: Information on Wyoming Roads]. State Planning Engineer, Wyoming Department of Transportation, Cheyenne, Wyoming.

Miller, W.R. 1981. Water resources of the southern Powder River area of southeastern Montana: Montana Bureau of Mines and Geology Memoir 47, 53 pages.

Miller, W.R., editor. 1999. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook. 256 pages.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, New York, NewYork. 722 pages.

Molnia, C.L., and F.W. Pierce. 1992. Cross Sections Showing Coal Stratigraphy of the Central Powder River Basin, Wyoming and Montana. U.S. Geological Survey Miscellaneous Investigations Map I–1959–D.

Montana Department of Environmental Quality and Wyoming Department of Environmental Quality. 2001. Montana and Wyoming Powder River Interim Water Quality Criteria Memorandum of Cooperation [Web Page]. Located at: http://www.wyomingcbm.com/DEQ/MT%20WY%20MOC%2018Aug01.htm. Accessed: August 1, 2001

Montana Department of Environmental Quality. 2002. Proposed 2002 Montana 303(d) List [Web Page]. Located at http://www.deq.state.mt.us/ppa/mdm/303_d/303d_information.asp . Accessed on August 26, 2002.

Moog, O. 1993. Quantification of daily peak hydropower effects on aquatic fauna and management to minimize environmental impacts. Regulated Rivers: Research and Management 8: 5-14.

Mount, D.R., Gulley, D.D., J.R. Hockett, Garrison, T.D., and J.M. Evans. 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphnia* *dubia*, *Daphnia magna*, and *Pimephales promelas* (fathead minnows). Environ. Toxicol. Chem. 16: 2009-2019.

Mueggler, Walter F., 1985. Vegetation Associations. *In:* DeByle, Norbert V., and Winokur, Robert P. Eds. Aspen: Ecology and Management in the Western United States. General Technical Report RM-119. U.S. Forest Service Rocky Mountain Range and Experiment Station, Fort Collins, Colorado.

Mulvey, M., and S. A. Diamond. 1991. Genetic factors and tolerance acquisitions in populations exposed to metals and metalloids. Pages 301-321 in M.C. Newman and A.W. McIntosh, editors. Ecotoxicology of metals: current concepts and applications. Lewis Publishers, Inc., Boca Raton, Florida.

Munn, L. 2002a. Interactions between Coal Bed Methane Product Water and Soils, Vegetation, Agriculture and Riparian Systems in the Powder River Basin. United States District Court for the District of Montana Billings Division. Case No. CV-01-96-BLG-RWA. Affadavit of Larry Munn. February 11.

Munn, L. 2002b. Soil and Crop Issues for Irrigators on the Tongue River Related to Coal Bed Methane Product Water. Study Completed for the Tongue River Water Users Association. February 15.

Murphey, P. C., P. Robinson, and J. Haessig. 2001. Paleontologic Resources of the Powder River Basin: Summary of Existing Conditions for the Powder River Basin Oil and Gas EIS. Rocky Mountain Paleontology, Longmont, Colorado. 24 pages.

Musselman, P. 2001. Personal communication. [*May 23* telephone conversation with K. Cloutier, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Information on Converse County planning and zoning]. County Planner, Converse County Planning Department, Douglas, Wyoming.

National Geographic. 1999. Field Guide to the Birds of North America. Third Edition. National Geographic, Washington, D.C.

National Invasive Species Council. 2001. Meeting the Invasive Species Challenge: National Invasive Species Management Plan. 80 pages.

National Scenic Byways Program. 2001. Wyoming Byways [Web Page]. Located at http://www.byways.org/travel/state.html?CX_STATE=WY. Accessed: August 7, 2001.

Natural Resources Conservation Service. 1971. Soil Survey of Powder River Area, Montana.

Natural Resources Conservation Service. 1975. Soil Survey of Johnson County, Wyoming.

Natural Resources Conservation Service. 1977. Soil Survey of Logan County, Colorado.

454

Natural Resources Conservation Service. 1983. Soil Survey of Crook County, Wyoming.

Natural Resources Conservation Service. 1986a. Soil Survey of Sheridan County Area, Wyoming.

Natural Resources Conservation Service. 1986b. Soil Survey of Converse County, Wyoming.

Natural Resources Conservation Service. 1986c. Soil Survey of Bighorn National Forest, Wyoming.

Natural Resources Conservation Service. 1990. Soil Survey of Weston County, Wyoming.

Natural Resources Conservation Service. 1997. Soil Survey of Natrona County Area, Wyoming.

Nature Conservancy. 1999. Northern Great Plains Steppe Ecoregional Plan. Provided via e-mail by Brian Martin of the Nature Conservancy office in Helena, Montana, on August 1, 2002.

Nelson, D. 1998a. Long-billed Curlew. Pages 182-183 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Nelson, D. 1998b. Upland Sandpiper. Pages 180-181 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Nelson, D. 1998c. Black Tern. Pages 194-195 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Nielsen, D. and M. Brock. 2001. Predicting the ecological consequences of increasing salinity on wetland sustainability. Department of Land and Water Conservation, New South Wales, Australia. Located at http://www.dlwc.nsw.gov.au/care/wetlands/activities/wetland_research.html. Accessed July 24, 2002.

Noise Pollution Clearinghouse (NPC). 2002. Fact Sheet. Noise Effects on Wildlife. Located at: http://www.nonoise.org/library/fctsheet/wildlife.htm. Accessed July 17, 2002.

Norling, B.S., S.H. Anderson, and W.A. Hubert. 1992. Roost sites used by sandhill crane staging along the Platte River, Nebraska. Great Basin Naturalist 52:253-261.

Noss, R.F., and A.Y. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press. Covelo, California.

BEST COPY AVAILABLE

Noss, R.F., and B. Csuti. 1994. Habitat Fragmentation. Pages 237-264 *in:* Meffe, G.K., and C.R. Carroll, eds. Principles of Conservation Biology. Sinauer Associates. Sunderland, Massachusetts.

O&G Environmental Consultants. 2001. CBM Operators Information Survey Results Report 2001, Prepared for Eastern Research Group, Inc., Chantilly, Virginia. September 7. 16 Pages.

Oedekoven, O.O. 2001. Sage grouse job completion report, Sheridan Region. Wyoming Game and Fish Department.

Oedekoven, O.O. 2002. Preliminary Sheridan Region lek site data. Wyoming Game and Fish Department

O'Hayre, A. 2002. Personal communication [*July 25* e-mail to K. Wilkerson, Greystone Environmental Consultants, Greenwood Village, Colorado *RE*: Regional Groundwater Flows]. Applied Hydrology and Associates, Inc., Denver, Colorado.

Olson, R.A. and W.A. Gerhart. 1982. A physical and biological characterization of riparian habitat and its importance in Wyoming. Wyoming Game and Fish Department, Cheyenne.

Orians, G.H. 1994. Global Biodiversity I: Patterns and Processes. Pages 78-109 *in:* Meffe, G.K., and C.R. Carroll, eds. Principles of Conservation Biology. Sinauer Associates. Sunderland, Massachusetts.

Oster, J., Grattan, S.R., and Tanji, K.K. 1998. Drought Tip 93-32: Maintaining Water Quality for Irrigated Agriculture Under Drought Conditions. Published by California Department of Water Resources-Water Conservation Office, Department of Land Air and Water Resources University of California, USDA Drought Response Office, and USDA Soil Conservation Service. [Website] Located at: http://lawr.ucdavis.edu/irrigation/drought_tips/dt32.htm. Accessed August 6, 2002.

Parrett, C., D. D. Carlson, and G. S. Craig, Jr. 1984. Floods of May 1978 in Southeastern Montana and Northeastern Wyoming. U.S. Geological Survey Professional Paper 1244. 74 pages.

Paton, P.W.C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology 8(1): 17-26.

Patton, T. M. 1997. Distribution and Status of Fishes in the Missouri River Drainage in Wyoming: Implications for Identifying Conservation Areas. Ph.D. Thesis, University of Wyoming, Laramie, Wyoming.

Payne, N. F., and F. C. Bryant. 1994. Techniques for wildlife habitat management of uplands. McGraw-Hill, Inc., New York, New York.

Payton, R. 2002. Personal Communication dated September 9, 2002, with Scott Archer, Senior Air Resource Specialist, USDI- Bureau of Land

456

Management, regarding Campbell County [Wyoming] PM_{10} monitoring data. Denver, Colorado.

Perry, C. and R. Overly. 1976. Impact of roads on big game distribution in portions of the Blue Mountains of Washington. Pages 62-68 *in:* S.R. Hieb, ed. Proceedings of the elk logging-roads symposium. Forestry Wildlife and Range Experiment Station, University of Idaho, Moscow.

Peterson, D.A. 1990. Invertebrate communities of small streams in northeastern Wyoming. U.S. Geological Survey. Water- Resources Investigations Report 85-4287. 45 pages.

Phillips, R.L., T.P. McEneaney, and A.E. Beske. 1984. Population densities of breeding golden eagles in Wyoming. Wildlife Society Bulletin 12:269-273.

Pierce, F.W., E.A. Johnson, C.L. Molnia, and W.R. Sigleo. 1990. Cross Sections Showing Coal Stratigraphy of the Southeastern Powder River Basin, Wyoming. U.S. Geological Survey Miscellaneous Investigations Map I–1959–B.

Pierson, A. 2001. Personal Communication [*April 9* Memorandum to BLM field managers and deputy state directors, BLM, Wyoming. *RE*: Issuance of BLM (Wyoming) Sensitive Species Policy and List.]

Pillard, D.A., Dufresne, D.L., Tietge, J.E., and J.M. Evans. 1999. Response to mysid shrimp (Mysidopsis bahia), sheepshead minnow (Cyprinodon variegates), and inland silverside minnow (Menidia beryllina) to changes in artificial seawater salinity. Environ. Toxicol. Chem. 18: 430-435.

Pimm, S.L. 1986. Community Stability and Structure. Pages 309-329 *in:* M.E. Soule, ed. Conservation Biology. The Science of Scarcity and Diversity. Sinauer Associates. Sunderland, Massachusetts.

Pitchford, M.L., and W.C. Malm. 1994. Development and Applications of a Standard Visual Index. *Atmospheric Environment* 28(5):1,049-54.

Potter, K. 1998a. American White Pelican. Pages 48-49 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Potter, K. 1998b. Black-crowned Night Heron. Pages 62-63 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Potter, K. and R. Roth. 1998. Fox Sparrow. Pages 474-475 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Preston, C. 1998a. Ferruginous Hawk. Pages 122-123 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

457

Preston, C.R. 1998b. Red-tailed Hawk. Pages 120-121 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Preston, C.R. 1998c. Swainson's Hawk. Pages 118-119 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Powder River CBM Information Council. 2001. Jobs & Economics [Web Page]. Located at http://www.cbmwyo.org/economics.htm. Accessed: August 11, 2001.

Pruiett, B. 1998. Personal communication. Natural Resources Specialist, U.S. Bureau of Land Management, Buffalo, Wyoming.

Questa Engineering Corporation (Questa). 2000. The 3M Coalbed Methane Reservoir Model Report. Questa Engineering Corporation, Golden, Colorado, unpublished report.

Quimby, D. C. 1951. The life history and ecology of the jumping mouse, *Zapus hudsonius*. Ecological Monographs 21:61–95.

Rabeni, C.F. and M.A. Smale. 1995. Effects of siltation on stream fishes and potential mitigating role of the buffering riparian zone. Hydrobiologia 303: 211-219.

Raines, G.L., and R.W. Marrs. 1983. Lithofacies Map, Cross Section, and Favorable Areas for Uranium Deposits, Powder River Basin, Wyoming and Montana. U.S. Geological Survey Miscellaneous Investigations Map I-1501.

Rankl, J. G., and M. E. Lowry. 1990. Ground-Water Flow Systems in the Powder River Structural Basin, Wyoming and Montana. U.S. Geological Survey Water-Resources Investigations Report 85–4229. 39 pages.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder, coordinators. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agriculture Handbook No. 703. 404 pages.

Rice, D.D. and T.M. Finn. 1995. Powder River Basin (033). *In:* Gautier, D.L. G.L. Dolton, K.I. Takahashi, and K.L. Varnes, eds. 1995 National Assessment of United States Oil and Gas Resources – Results, Methodology, and Supporting Data. U.S. Geological Survey Digital Data Series DDS-30, CD-ROM.

Rice, C.A., M.S. Ellis, and J.H. Bullock, Jr. 2000. Water Co-produced with Coalbed Methane in the Powder River Basin, Wyoming: Preliminary Compositional Data. Open-File Report 00-372. U.S. Geological Survey, Denver, Colorado. 18 pages.

Rice, C.A., T.T. Bartos, and M.S. Ellis. 2002. Chemical and Isotopic Composition of Water in the Fort Union and Wasatch Formations of the Powder River Basin, Wyoming and Montana: Implications for Coalbed Methane Development. Pages 53-70 *in* S.D. Schwochow and V.F. Nuccio, eds. Coalbed Methane of North America II. Rocky Mountain Association of Geologists volume. 108 pages.

Ringen, B. H., and P. B. Daddow. 1990. Hydrology of the Powder River Alluvium between Sussex, Wyoming and Moorhead, Montana. U.S. Geological Survey Water-Resources Investigations Report 89–4002. 47 pages.

Rocky Mountain Front Visitors Guide. 2002. Hutterites: Montana's Quiet, Communal Farms [Web Page]. Located at http://www.chotequacantha.com/display/inn_visitor/History/%20Culture%20And&20Reservations.html. Accessed: July 30, 2002.

Rogers, G. S. 1918. Baked Shale and Slag Formed by the Burning of Coal Beds. U.S. Geological Survey Professional Paper 108A. 10 pages.Rost, G.R. and J.A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43: 634-641.

Rothwell, R. 1992. Antelope, sage grouse, and neotropical migrants. *In:* Finch, D.M. and P.W. Stangel, eds. Status and Management of Neotropical Migratory Birds. USDA Forest Service General Technical Report RM-229. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Rowland, M.M., M.J. Wisdom, B.K. Johnson, and J.G. Kie. 2000. Elk distribution and modeling in relation to roads. Journal of Wildlife Management 64(3): 672-684.

Ryder, R. 1998a. Snowy Egret. Pages 56-57 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Ryder, R. 1998b. White-faced Ibis. Pages 64-65 *in:* Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Saab, V.A., and T.D. Rich. 1997. Large-scale conservation assessment for neotropical migratory land birds in the interior Columbia River basin. USDA Forest Service, General Technical Report PNW-GTR-399. Portland, Oregon.

San Miguel Basin Sage Grouse Working Group. 1998. Final Gunnison Sage Grouse Conservation Plan. San Miguel Basin, Colorado.

San Miguel Basin Sage Grouse Working Group. 1998. Final Gunnison Sage Grouse Conservation Plan. San Miguel Basin, Colorado. Last Revise 17 July 1998.

Sawyer, C., and B. Jeffries. 1999. Downstream gathering and transportation of coal bed methane in the Powder River Basin Wyoming. Pages 83–86 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, Results and Analysis 1966 - 2000. Version 2001.2, U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, MD.

Sauer, J. R., J. E. Hines, and J. Fallon. 2002. The North American Breeding Bird Survey, Results and Analysis 1966 - 2001. Version 2002.1, U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, MD. Located at http://www.mbr-pwrc.usgs.gov/bbs/bbs2001.html. Accessed August 8, 2002.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5(1): 18-32.

Schroeder, M.A., J.R. Young, and C.E. Braun. 1999. Sage grouse (*Centrocercus urophasianus*). *In:* The Birds of North America, No. 425 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Pennsylvania.

Seacross Enterprises. 2002. Wildlife communities of the Powder River Basin: a baseline document to assist in evaluating impacts of coal bed methane development. Unpublished document prepared by Seacross Enterprises, Gillette, Wyoming.

Seeland, D. A. 1976. Relationships between early Tertiary sedimentation patterns and uranium mineralization in the Powder River Basin, Wyoming. Pages 53–64 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Seeland, D. A. 1992. Depositional Systems of a Synorogenic Continental Deposit — The Upper Paleocene and Lower Eocene Wasatch Formation of the Powder River Basin, Northeast Wyoming. U.S. Geological Survey Bulletin 1917–H. 20 pages.

Seelig, B.D. 2000. Salinity and sodicity in North Dakota soils. Publication EB 57 (May). North Dakota State University Extension Service. Located at http://www.ext.nodak.edu/extpubs/plantsci/soilfert/eb57-1.htm and http://www.ext.nodak.edu/extpubs/plantsci/soilfert/eb57-2.htm Accessed July 24, 2002. 17 pages.

Seiler, R. L., J. P. Skorupa, and others. 1999. Areas Susceptible to Irrigation-Induced Selenium Contamination of Water and Biota in the Western United States. U.S. Geological Survey Circular 1180. 36 pages.

Shafroth, Patrick B., Jonathan M. Friedman, and Lee S. Ischinger. 1995. Effects of Salinity on Establishment of *Populus fremontii* (Cottonwood) and *Tamarix*

YGO

Ramosissima (Saltcedar) in Southwestern United States. Great Basin Naturalist 55(1) 58-65.

Sheridan County. 1982. An Update of the Comprehensive Plan for Sheridan County, Wyoming, adopted 1979 and updated 1982. CSSA/Wyoming, Cheyenne, Wyoming.

Sheridan County. 1999. Sheridan County, Wyoming Comprehensive Land Use Plan. October 1980, updated 1999, Sheridan County Planning Department, Sheridan, Wyoming.

Sheridan County. 2001a. Draft Vision 2020, Sheridan County Growth Management Plan, adopted May 7, 2001. Sheridan County, Sheridan, Wyoming.

Sheridan County. 2001b. Sheridan County Zoning Resolution, adopted May 14, 1985, amended February 6, 2001. Sheridan County, Sheridan, Wyoming.

Shickley, G. M. 1961. Wintering Bald Eagles in Nebraska. 1959–1960. Nebraska Bird Review 29:26–31.

Shirley, K. 2000. Wyoming Enjoys Coal Gas Play [Web Page]. American Association of Petroleum Geologists, Explorer for April 2000. Located at http://www.aapg.org/explorer/archives/04_00/powder.html. Accessed: August 22, 2001.

Siegley, C.E., R.E.J. Boerner, and J.M. Reutter. 1988. Role of the seed bank in the development of vegetation on a freshwater marsh created from dredge spoil. Journal of Great Lakes Research 14: 267-276.

Skaar, D. 2001. Use of bicarbonate concentrations as a measure of toxic effects to aquatic life in the Powder and Tongue Rivers. Montana fish, Wildlife and Parks. 1 p.

Slagle, S.E., B.D. Lewis, and R.W. Lee. 1985. Ground-Water Resources and Potential Hydrologic Effects of Surface Coal Mining in the Northern Powder River Basin, Southeastern Montana. U.S. Geological Survey Water-Supply Paper 2239, 34 pages.

Smith, J.B., and W.A. Hubert. 1989. Use of a tributary by fishes in a Great Plains river system. Prairie Naturalist 21: 27-38.

Smith, G. 2001. Personal communication [*June 15* telephone conversation with K. Mullins, Greystone, Greenwood Village, Colorado. *RE:* the status of community detention]. Campbell County Detention Center, Gillette, Wyoming.

South Dakota Department of Environment and Natural Resources. 2002. South Dakota Total Maximum Daily Load Waterbody List 2002 (Draft) [Web Page]. Located at: www.state.sd.us/denr/DFTA/WatershedProtection/WQInfo.htm. Accessed on August 26, 2002.

Spahr, R., L. Armstrong, D. Atwood, and M. Rath. 1991. Threatened, Endangered, and Sensitive Species of Intermountain Region. U.S. Forest Service, Ogden, Utah.

Spencer, D. A. 1976. Wintering of the Migrant Bald Eagle in the Lower 48 States. National Agricultural Chemicals Assoc. Washington, D.C. 170 pages.

Springer, S. 2001. Personal communication. [*May 23* telephone conversation with K. Cloutier, Greystone, Greenwood Village, Colorado. *RE:* Information on Sheridan County planning and zoning]. County Planner, Sheridan County Planning Department, Sheridan, Wyoming.

State of Wyoming. 2002a. Title 11 Agriculture, Livestock and Other Animals. Chapter 16 Wyoming Conservation Districts Law. §11-16-103. 18 pages.

State of Wyoming. 2002b. Title 11 Agriculture, Livestock and Other Animals. Chapter 5 Weed and Pest Control. §11-5-102. 2 pages.

State of Wyoming. 2002c. Title 35 Public Health and Safety. Chapter 11 Environmental Quality, Article 1 General Provisions, Wyoming Environmental Quality Act. §35-11-309. 10 pages.

State of Wyoming. 2002d. Title 41 Water. Chapter 3 Water Rights, Administration and Control, Article 10 Instream Flows. §41-3-1001. 6pp.

Stebbins, R.C. 1985. A Field Guide to Western Reptiles and Amphibians. Second edition. Houghton Mifflin Company, Boston, Massachusetts.

Steenhof, K. 1978a. The Ecology of Wintering Bald Eagles in Southeastern South Dakota. M.S. Thesis. University of Missouri, Columbia, Missouri. 148 pages.

Steenhof, K. 1978b. Management of wintering bald eagles. U.S. Fish and Wildlife Service, Biological Services Program, FWS/OBS-78/79.Sheridan County. 1975. Airport Master Plan. Sheridan County, Sheridan, Wyoming.Stebbins, R. C. 1985. A Field Guide to Western Reptiles and Amphibians. Second edition. Houghton Mifflin Company, Boston, Massachusetts.

Stewart, B. 1995. Tongue River Basin Management Plan. Wyoming Game and Fish Department. Sheridan, Wyoming.

Stewart, B. 1996. Little Powder Basin Management Plan (FXSN8LP). Wyoming Game and Fish Department, Sheridan, Wyoming.

Stewart B. 2001. Personal communication [*December 6* e-mail to Patrick Golden, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE:* Basin Management Plans for Sheridan and Casper Regions]. Fisheries Management Coordinator, Wyoming Game and Fish Department, Cheyenne, Wyoming.

Stewart, C. L., L. J. Reimann, and S. M. Swapp. 1999. Mineralogic considerations for uranium in-situ leach mining: A preliminary study of uranium and associated mineralogy of roll-front uranium deposits in Wyoming and Nebraska. *Pages* 155–165 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

Strand J.R. 2002. Personal Communication [*July 31* telephone conversation with K. Mullins, Greystone Environmental Consultants RE: Hutterite/Amish Populations, Locations and Culture]. Executive Director, Lewiston Chamber of Commerce, Lewiston, Montana.

Stromberg, M. R., D. E. Biggins, and M. Bidwell. 1981. New record of the least weasel in Wyoming. Prairie Naturalist. 13 (2):45–46.

Stone, E. In press. Separating the noise from the noise. A finding in support of the "niche hypothesis," that birds are influenced by human induced noise in natural habitats. Received by e-mail from E. Stone on May 9, 2002.

Swanson, R. B., M. L. Smalley, R. E. Woodruff, M. L. Clark. 2001. Water Resources Data, Wyoming, Water Year 2000. U.S. Geological Survey Water-Data Report WY–00–1. 457 pages.

Swanson, R.B., R.E. Woodruff, G.A. Laidlaw, K.R. Watson, and M.L. Clark. 2002. Water Resources Data, Wyoming, Water Year 2001; Volume 1, Surface Water. U.S. Geological Survey Water-Data Report WY-01-1, 586 pages.

Swisher, J. F. 1964. A roosting area of the bald eagle in northern Utah. Wilson Bulletin 76(2):186–187.

Taylor, O. J. 1978. Summary Appraisals of the Nation's Groundwater Resources-Missouri River Basin. Geological Survey Professional Paper 813–Q. 41 pages.

Terres, J. K. 1980. The Audubon Society Encyclopedia of North American Birds. Alfred A. Knopf. New York, New York.

Tidball R. R., and R. J. Ebens. 1976. Regional geochemical baselines in soils of the Powder River Basin, Montana-Wyoming. Pages 299–310 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Town of Wright. 1998. Town of Wright Master Plan Revision, December 1998. Town of Wright, Wright, Wyoming.

Tribal Leaders Council. 2001a. Crow Reservation [Web Page]. Located at http://tlc.wtp.net/crow.htm. Accessed: May 17, 2001.

Tribal Leaders Council. 2001b. Northern Cheyenne Reservation [Web Page]. Located at http://tlc.wtp.net/northern.htm. Accessed: May 17, 2001.

Trimble, D. E. 1980. The Geologic Story of the Great Plains. U.S. Geological Survey Bulletin 1493. 55 pages.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects on roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30.

Udvardy, M. D. 1977. The Audubon Society Field Guide to North American Birds, Western Region. Alfred A. Knopf Publishing. New York, New York.

University of Utah. 2001. Personalizing the Earthquake Threat [Web Page]. Located at http://www.seis.utah.edu/NEHRP_HTM/perseq.htm. Accessed: August 22, 2001.

University of Wyoming. 2002. Wyoming Natural Resources Clearinghouse — Data Atlas. Terrestrial Vertebrate Species Richness in Wyoming [Web Page]. Located at http://www.wygisc.uwyo.edu/24k/vert.html. Accessed: August 6, 2002.

Unruh, J.D., Jr., 1982 The Plains Across: The Overland Emigrants and the Trans-Mississippi West, 1840-60. University of Illinois Press, Urbana and Chicago, Illinois.

U.S. Bureau of Land Management. 1981. Final Powder River Regional Coal Environmental Impact Statement. U.S. Bureau of Land Management, Wyoming State Office, Cheyenne, Wyoming.

U.S. Bureau of Land Management. 1982. Platte River Resource Area Oil and Gas Environmental Assessment. Casper District Office, Casper, Wyoming.

U.S. Bureau of Land Management. 1983. Final Environmental Impact Statement on the Riley Ridge Natural Gas Project, Sublette, Lincoln, and Sweetwater Counties, Wyoming. BLM-YA-ES-84-002-1327. Prepared by Environmental Research and Technology, Inc., for the U.S.D.I. Bureau of Land Management, Wyoming State Office. Cheyenne, Wyoming.

U.S. Bureau of Land Management. 1984. Platte River Resource Area Resource Management Plan Draft Environmental Impact Statement. Casper District Office, Casper, Wyoming.

U.S. Bureau of Land Management. 1985a. Bureau of Land Management Manual, Section 9113 — Roads. Engineering Rel. 9–247.

U.S. Bureau of Land Management. 1985b. Platte River Resource Area Management Plan Record of Decision. Casper District Office, Casper, Wyoming. 93 pages.

U.S. Bureau of Land Management. 1985c. Resource Management Plan Record of Decision. Buffalo District Office, Buffalo, Wyoming.

464

U.S. Bureau of Land Management. 1986. Visual Resource Inventory Manual H-8410-1 and Visual Contrast Rating Manual H-8431-1. BLM Lands and Renewable Resources.

U.S. Bureau of Land Management. 1991a. Riparian-wetland initiative for the 1990s. BLM/WO/GI–91/001 +4340.

U.S. Bureau of Land Management. 1991b. Wyoming Supplement to the Bureau 9113 Manual. Wyoming State Office, Cheyenne, Wyoming. 16 pages.

U.S. Bureau of Land Management. 1992a. American Oil and Gas Marquiss Field Coal Bed Methane Project Environmental Assessment. Environmental Assessment No. WY–061–2–082. Casper, Wyoming.

U.S. Bureau of Land Management. 1992b. Exxon Pistol Point Coal Bed Methane Project Environmental Assessment. Environmental Assessment No. WY–061–2–079. Buffalo Resource Area, Buffalo, Wyoming.

U.S. Bureau of Land Management. 1995a. Wyoming BLM Mitigation Guidelines. Buffalo, Wyoming.

U.S. Bureau of Land Management. 1995b. Gillette South Coalbed Methane Project Draft Environmental Impact Statement. Casper District Office, Buffalo Resource Area. Buffalo, Wyoming.

U.S. Bureau of Land Management. 1995c. Lighthouse Coal Bed Methane Project Environmental Assessment. Casper, Wyoming.

U.S. Bureau of Land Management. 1995d. Noxious Weeds: A Growing Concern. Washington, D.C.

U.S. Bureau of Land Management. 1996a. Gillette North Coal Bed Methane Project Environmental Assessment. Environmental Assessment No. WY–061–7–EA–027. Buffalo, Wyoming.

U.S. Bureau of Land Management. 1996b. Partners Against Weeds: An Action Plan for the Bureau of Land Management. http://www.blm.gov/education/weed/paws, January 1996

U.S. Bureau of Land Management. 1997a. Gillette South Coalbed Methane Project Final Environmental Impact Statement. Buffalo, Wyoming.

U.S. Bureau of Land Management. 1997b. Standards for Healthy Rangelands and Guidelines for Management for Public Lands Administered by Bureau of Land Management in the State of Wyoming. Buffalo, Wyoming.

U.S. Bureau of Land Management. 1997c. U.S. Bureau of Land Management, Casper Field Office, Buffalo, Wyoming (see page 3-108).

U.S. Bureau of Land Management. 1998. Ferron Natural Gas Project, Draft Environmental Impact Statement. Utah State Office, Salt Lake City, Utah.

965

U.S. Bureau of Land Management. 1999a. Ferron Natural Gas Development Project Final Environmental Impact Statement. Utah State Office, Salt Lake City, Utah. 400 pages.

U.S. Bureau of Land Management. 1999b. Lower Prairie Dog Creek Coal Bed Methane Project Environmental Assessment. EA# WY 0070-9-EA-238. Buffalo Field Office, Buffalo, Wyoming. 83 pages.

U.S. Bureau of Land Management. 1999c. Wyodak Coal Bed Methane Project Draft Environmental Impact Statement. Buffalo Field Office, Buffalo, Wyoming.

U.S. Bureau of Land Management. 1999d. Wyodak Coal Bed Methane Project Final Environmental Impact Statement. Wyoming State Office, Cheyenne, Wyoming. 300 pages

U.S. Bureau of Land Management. 1999e. Final Environmental Impact Statement - Continental Divide/Wamsutter II Natural Gas Project, Sweetwater and Carbon Counties. Rawlins and Rock Springs Field Offices. Rawlins and Rock Springs, Wyoming.

U.S. Bureau of Land Management (BLM). 2000a. Coal Bed Methane Development in the Northern San Juan Basin of Colorado, A Brief History and Environmental Observations, a working document compiled by the San Juan Field Office, December 1999, amended March 2000. Durango, Colorado.

U.S. Bureau of Land Management. 2000b. Wyodak Drainage Coal Bed Methane Environmental Assessment. EA # WY-070-01-034. Buffalo Field Office, Buffalo, Wyoming.

U.S. Bureau of Land Management (BLM). 2000c. Bureau of Land Management Strategic Plan: FY 2000 – 2005. http://www.blm.gov/nhp/info/stratplan/strat0105.pdf. Accessed: August 2000.

U.S. Bureau of Land Management. 2001a. Approved Resource Management Plan for Public Lands administered by the Bureau of Land Management Buffalo Field Office, Buffalo, Wyoming.

U.S. Bureau of Land Management. 2001b. Interim Drainage Report on Coalbed Methane Development in T43–52N, R70–75W, Campbell County, Wyoming. Buffalo, Wyoming.

U.S. Bureau of Land Management. 2001c. Personal communication [*March 30* memorandum on Wyoming state taxes on oil and gas. Deputy State Director, Mineral and Lands, Wyoming State Office, Cheyenne, Wyoming. Memorandum No. WY–38]. Wyoming State Office, Cheyenne, Wyoming.

U.S. Bureau of Land Management. 2001d. Powder River Basin Coal Production [Web Page]. Located at http://www.wy.blm.gov/minerals/ coal/prb/pages/PRB_coalpro.html. Accessed: August 15, 2001.

466

U.S. Bureau of Land Management. 2001e. Powder River Basin Oil and Gas Environmental Impacts Analysis Geographic Information System Database. Buffalo, Wyoming.

U.S. Bureau of Land Management. 2001f. Reasonably Foreseeable Development Scenario for Oil and Gas Development in the Buffalo Field Office Area. Buffalo Field Office, Buffalo, Wyoming. 28 pages.

U.S. Bureau of Land Management. 2002. Montana Statewide Draft Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans. U.S. Department of the Interior and State of Montana, BLM document number BLM/MT/PL-02/003.

U.S. Census Bureau. 1990. Occupany of Housing [Web Page]. Located at http://venus.census.gov/cdrom/lookup/991684778. Accessed: June 4, 2001.

U.S. Census Bureau. 1997. Percentage of the total population by poverty level for county and state [Web Page]. Located at: http://www.census.gov/hhes/www/saip/stcty/a97-56.htm. Accessed on May 24, 2001.

U.S. Census Bureau. 1999. State and County Quickfacts, Population Information [Web Page]. Located at http://quickfacts.census.gov/qfd/states/56/html. Accessed: May 31, 2001.

U.S. Census Bureau. 2000a. Census 2000 Population between 1920 and 1990 [Web Page]. Located at: http://www.census.gov.population..cencounts/wy/90090.txt. Accessed: May 15, 2001.

U.S. Census Bureau. 2000b. Median household income [Web Page]. Located at http://factfinder.census.gov. Accessed: May 15, 2001.

U.S. Census Bureau. 2000c. Housing Costs [Web Page]. Located at http://factfinder.census.gov/hunits/states/56cty.htm. Accessed: May 15, 2001.

U.S. Census Bureau. 2000d. Racial Composite by County and State for 2000 [Web age]. Located at http://factfinder.census.gov. Accessed: May 15, 2001.

U.S. Census Bureau. 2000e. Percentage of the Total Population by Selected Age Groups for County and State [Web Page]. Located at http://www.census.gov/population/estimates/county/ca/camt99.htm. Accessed: May 24, 2001.

U.S. Census Bureau. 2001. Census 2000 Housing Units [Web Page]. Located at http://quickfacts.census.gov/hunits/states/56cty.html. Accessed: May 31, 2001.

U.S. Department of Transportation, Federal Highway Administration. 1999. Invasive Species: Executive Order 13112, February 3, 1999 [Web Page]. Located at http://www.fhwa.dot.gov/environment/020399em.htm Accessed: July 19, 2002.

U.S. Environmental Protection Agency. 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms, 2nd ed. EPA/600/4-91/003. Washington, D.C. 470 pages.

U.S. Environmental Protection Agency. 1988. Control of Open Fugitive Dust Sources. EPA-450/3-88-008. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency. 1997a. National Air Toxics Information Clearinghouse (NATICH) Database. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency. 1997b. Integrated Risk Information System (IRIS) Database. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency. 1998. Response to Peer Review Comments of CALMET/CALPUFF Modeling System. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency. 1999. Protocol for developing Sediment TMDLs. EPA 841-B-99-004. Office of Water (4503F) Washington, D.C. 132 pages.

U.S. Environmental Protection Agency. 2000. Compilation of Air Pollutant Emission Factors, AP-41, Volume I: Stationary Point and Areas Sources, and Volume II: Mobile Sources, Fifth Edition. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. (http://www.epa.gov/ttn/chief/ap42/index.html)

U.S. Environmental Protection Agency. 2001a. Safe Drinking Water Query Form [Web Page]. Located at: http://www.epa.gov/enviro/html/sdwis/sdwis_query. html. Accessed: September 12, 2001.

U.S. Environmental Protection Agency. 2001b. Economic Impact Analysis of Disposal Options for Produced waters from Coalbed Methane Operations in EPA Region 8. U.S.EPA Public Meeting Presentation, Septemer 25, 2001, Billings, Montana.

U.S. Environmental Protection Agency (EPA). 2002a. Draft Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs. EPA Office of Water, document number EPA 816-D-02-006.

U.S. Environmental Protection Agency. 2002b. Letter to Al Pierson, State Director of the BLM, Wyoming State Office RE: EPA's Review of the Draft Environmental Impact Statement (Draft EIS) and Draft Planning Amendment for the Powder River Basin Oil and Gas Project (CEQ #020017). Drafted by the EPA Region 8 Office, Denver, Colorado. May 15, 2002.

BEST COPY AVAILABLE

U.S. Environmental Protection Agency. 2002c. Opportunities to Reduce Anthropogenic Methane Emissions in the United States [Web Page]. Located at: http://www.epa.gov/ghginfo/reports/oppor.htm. Accessed on: July 29, 2002.

U.S. Environmental Protection Agency. 2002d Surf Your Watershed [Web Page]. Located at http://cfpub.epa.gov/surf/state.cfm?statepostal=WY. Accessed: July 30, 2002.

U.S. Environmental Protection Agency. 2002e. AirData: Access to Air Pollution Data. Located at: http://www.epa.gov/air/data/monvals.html?st~WY~Wyoming. Accessed August 14.

U.S. Environmental Protection Agency. 2000f. Watershed Profile for the State of Wyoming. Surf Your Watershed Website, located at http/cfpub.epa.gov/surf/state.cfm?statepostal=WY. Accessed August 14.

U.S. Fish and Wildlife Service. 1970. Final Rule to List Animal *Mustela nigripes* (black-footed ferret) as an Endangered Species. Federal Register 35 FR 8491–8498.

U.S. Fish and Wildlife Service. 1987. Aquatic Cycling of Selenium: Implications for Fish and Wildlife. U.S. Fish and Wildlife Service. 10 pages.

U.S. Fish and Wildlife Service. 1989. Black-footed Ferret Survey Guidelines for Compliance with the Endangered Species Act. Denver, Colorado, and Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 1992. Final Rule to List the Plant *Spiranthes diluvialis* (Ute Ladies'-Tresses) as a Threatened Species. January 17, 1992. Federal Register 57 (12): 2048-2053.

U.S. Fish and Wildlife Service. 1995. Final Rule to Reclassify the Bald Eagle from Endangered to Threatened in All of the Lower 48 States. July 12, 1995. Federal Register 60(133): 36000–36010.

U.S. Fish and Wildlife Service. 1998. Final Rule to List the Preble's Meadow Jumping Mouse as a Threatened Species. May 13, 1998. Federal Register 63 (92): 26517-26530.

U.S. Fish and Wildlife Service. 1999a. Proposed threatened status for the mountain plover. February 16, 1999. Federal Register 64(30):7587–7601.

U.S. Fish and Wildlife Service. 1999b. Extension of comment period and announcement of public hearings on proposal to list the mountain plover as a threatened species. April 19, 1999. Federal Register 64(74):19108.

U.S. Fish and Wildlife Service. 1999c. Final rule to remove the American peregrine falcon from the federal list of endangered and threatened wildlife, and to remove the similarity of appearance provision for free-flying peregrines in

BEST COPY AVAILABLE

the conterminous United States. August 25, 1999. Federal Register 64(164):46542–46558.

U.S. Fish and Wildlife Service. 2000. 12-Month Finding for a Petition to List the Black-Tailed Prairie Dog as Threatened. February 4, 2000. Federal Register 65(24): 5476-5488.

U.S. Fish and Wildlife Service. 2001a. Annual Notice of Findings on Recycled Petitions. January 8, 2001. Federal Register 66(5): 1295-1300.

U.S. Fish and Wildlife Service. 2001b. 90-day finding for a petition to list the Yellowstone cutthroat trout as threatened. February 23, 2001. Federal Register 66(37): 11244-11249.

U.S. Fish and Wildlife Service. 2001c. 12-month finding for a petition to list the sicklefin chub (*Macrhybopsis meeki*) and the sturgeon chub (*Macrhybopsis gelida*) as endangered. April 18, 2001. Federal Register 66(75): 19910-19914.

U.S. Fish and Wildlife Service (USFWS). 2001d. Annual Notice of Findings on Recycled Petitions. Federal Register 66(5): 1295-1300.

U.S. Fish and Wildlife Service (USFWS). 2001e. 12-month finding for a petition to list the sicklefin chub (*Macrhybopsis meeki*) and the sturgeon chub (*Macrhybopsis gelida*) as endangered. Federal Register 66(75):19910-19914.

U.S. Fish and Wildlife Service. 2002a. Review of Species that Are Candidates or Proposed for Listing as Endangered or Threatened; Annual Notice of Findings on Recycled Petitions; Annual Description of Progress on Listing Actions. June 13, 2002. Federal Register 67(114): 40657-40679.

U.S. Fish and Wildlife Service. 2002b. Mountain Plover Survey Guidelines. U.S. Fish and Wildlife Service.

U.S. Forest Service. 1985. Land and Resource Management Plan for the Medicine Bow National Forest and Thunder Basin National Grassland. Medicine Bow National Forest, Laramie, Wyoming.

U.S. Forest Service. 1987. Plant Associations of Region Two, Edition 4. USFS Publication RC–ECOL–87–2. USFS, Rocky Mountain Region, Denver, Colorado. 429 pages.

U.S. Forest Service. 1994. Oil and Gas Leasing on the Thunder Basin National Grassland, Douglas Ranger District, Final Environmental Impact Statement. Medicine Bow National Forest, Laramie, Wyoming.

U.S. Forest Service. 2000. Screening Methodology for Calculating ANC Change to High Elevation Lakes. Published by the USDA-Forest Service, Rocky Mountain Region. Lakewood, Colorado.

BEST COPY AVAILABLE

U.S. Forest Service. 2001a. Land and Resource Management Plan for the Thunder Basin National Grassland, Medicine Bow-Routt National Forest. Rocky Mountain Region, 2001 [Web Page]. Located at http://www.fs.fed.us/ngp/final/pdf_plan_final/Thunder_Basin_Plan/titlepage.pdf. Accessed: September 13, 2001.

U.S. Forest Service. 2001b. Shooting Restriction Applied to Thunder Basin Ferret Reintroduction Areas [Web Page]. Located at http://www.fs.fed.us/mrnf/press/042401_shooting.html. Accessed: May 23, 2001.

U.S. Forest Service. 2001c. Rocky Mountain Region Endangered, Threatened, Proposed, and Sensitive Species List. November 2001.

U.S. Forest Service. 2002. Record of Decisions for the Final Environmental Impact Statement and Land and Resource Management Plan Revision for Thunder Basin National Grassland. USDA Forest Service, Rocky Mountain Regional Office, Denver, Colorado. 47 pages + addendum.

U.S. Geological Survey. 1974. Shallow Ground Water in Selected Areas in the Fort Union Coal Region. U.S. Geological Survey Open-file Report 74-371. Prepared by the Ground-water Subgroup of Water Work Group, Northern Great Plains Resource Program.

U.S. Geological Survey. 1981. Report on Climate, Air Quality, and Noise for the Cache Creek-Bear Thrust Environmental Impact Statement, Open file Report 83-859 by Paul W. Kruger, Billings, Montana, June 1981.

U.S. Geological Survey. 1995. Water Use in the United States [Web Page]. Located at http://water.usgs.gov/watuse/spread95/wyh895.txt. Accessed: June 1, 2001.

U.S. Geological Survey. 1997. Coalbed Methane—An Untapped Energy Resource and an Environmental Concern. U.S. Geological Survey Fact Sheet FS-019-97.

U.S. Geological Survey, Fort Union Coal Assessment Team. 1999. 1999 Resource Assessment of Selected Tertiary Coal Beds and Zones in the Northern Rocky Mountains and Great Plains Region. U.S. Geological Survey Professional Paper 1625–A. CD ROM Disks 1 and 2.

U.S. Geological Survey. 2000. Water Produced with Coal-Bed Methane. U.S. Geological Survey Fact Sheet FS-156-00, November 2000.

U.S. Geological Survey. 2001a. Water Resources of the United States [Web Page]. Located at http://water.usgs.gov/nwis/. Accessed: June 1, 2001.

U.S. Geological Survey. 2001b. Earthquake History of Colorado [Web Page]. Located at: http://neic.usgs.gov/neis/states/colorado/colorado_history.html. Accessed: August 22, 2001.

U.S. Geological Survey. 2001c. Boreal Toad Homepage [Web Page]. Located at http://www.mesc.usgs.gov/borealtoad. Accessed: July 3, 2001. Updated site located at http://www.mesc.usgs.gov/resources/education/borealtoad. Accessed September 17, 2002.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and Improvement of Saline and Alkali Soils. Agriculture Handbook No. 60 (February). Soil and Water Conservation Research Service, Agricultural Research Service, U.S. Department of Agriculture. U.S. Government Printing Office, Washington, DC. 160 pages.

U.S. Soil Conservation Service. 1994. Utah Guide for Soil Survey Manuscripts. Supplement to National Soil Survey Handbook. U.S. Soil Conservation Service. Salt Lake City, Utah.

Vannote, R.L. and B.W. Sweeney. 1980. Geographic analysis of thermal equilibria: a conceptual model for evaluating the effects of natural and modified thermal regimes on aquatic insect communities. American Naturalist 115: 667-695.

Voights, D.K. 1976. Aquatic invertebrate abundance in relation to changing marsh vegetation. American Midland Naturalist 95: 312-322.

Ward, A.L. 1976. Elk behavior in relation to timber harvest operations and traffic on the Medicine Bow Range in south-central Wyoming. Pages 32-43 *in:* Proceedings of the Elk-Logging-Roads Symposium, University of Idaho, Moscow.

Wagner, G. 1997. Status of the Northern Leopard Frog (*Rana pipiens*) in Alberta. Alberta Environmental Protection, Wildlife Management Division, Wildlife Status Report No. 9, Edmonton, AB. 46 pages.

Wells, D. K. 1982. Ground-water Data from Selected Wells in Alluvial Aquifers, Powder River Basin and Adjacent Areas, Northeastern Wyoming. U.S. Geological Survey Open-File Report 82-856. 35 pages.

Welp, L., W.F. Fertig, G.P. Jones, G.P. Beauvais, and S.M. Ogle. 2000. Fine Filter Analysis of the Bighorn, Medicine Bow, and Shoshone National Forests in Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming.

Wendell, W. G., G. B. Glass, R. M. Breckenridge, F. K. Root, and D. Lageson. 1976. Geologic Map Atlas and Summary of Land, Water, and Mineral Resources, Johnson County, Wyoming. Wyoming State Geological Survey County Resource Series No. 4.

Wester-Wetstein and Associates, Inc. 1999. Personal communication [*April 20* written communication with Bill Carson, City of Gillette, regarding well testing]. Wester-Wetstein and Associates, Inc., Laramie, Wyoming.

Western Gas Resources, Incorporated (WGRI). 2001. Alternative Methods to Disposing of Produced Water Being Utilized or Considered by CBM Operators. Unpublished Document. Western Gas Resources, Incorporated. Denver, Colorado. 3 pages.

Westlands Water District. 2002. Salinity and Drainage in *Water Management Handbook*. [Website]. http://www.westlandswater.org/wtrcon/handbook/salinity.htm. Accessed August 8, 2002.

Whitaker, J. O., Jr. 1963. A study of the meadow jumping mouse, *Zapus hudsonius* (Zimmerman), in central New York. Ecological Monographs 33:3.

Whitehead, R. L. 1996. Ground Water Atlas of the United States, Segment 8 — Montana, North Dakota, South Dakota, Wyoming. U.S. Geological Survey Hydrologic Investigations Atlas 730-I. 24 pages.

Wilcove, D.S., C.H. McLellan, and A.P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pages 237-256 *in*: M.E. Soule, ed. Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates. Sunderland, Massachusetts.

Wiley, B. 2001a Personal communication [*November 21* email to Steven Faulk, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE*: Basin Management Plans for Sheridan and Casper Regions]. Fisheries Management Coordinator, Wyoming Game and Fish Department. Cheyenne, Wyoming.

Wiley, B. 2001b. Personal communication [*December 4* fax to Patrick Golden, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE*: Native Species Status (NSS) of Fish and Amphibian Species Native to WYoming (January 11, 2001)]. Fisheries Management Coordinator, Wyoming Game and Fish Department, Cheyenne, Wyoming.

Williams, V. S. 1978. Surficial Geologic Map of the Moyer Springs Quadrangle, Campbell County, Wyoming. U.S. Geological Survey Miscellaneous Field Studies Map MF-950.

Wilson, J.B. 1988. The cost of heavy-metal tolerance: an example. Evolution 42:408-413.

Winn, R. 1998a. American Kestrel. Pages 126-127 *in*: Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Winn, R. 1998b. Flammulated Owl. Pages 210-211 *in*: Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.Wolfbauer, C. A. 1976. Bentonite in the Powder River Basin, Wyoming. Pages 257-259 *in* R. B. Laudon, editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

BEST COPY AVAILABLE

Wolf, J. K. 2002. Personal communication [*November 22 letter to A. Reese, Wyoming Office of Federal Lands Policy, Cheyenne, Wyoming. RE:* Preliminary Final Environmental Impact Statement and Draft Planning Amendment for the Powder River Basin Oil and Gas Project (SHPO File #1001GGy001)]. Review and Compliance Program Manager, Wyoming State Historical Preservation Office, Cheyenne, Wyoming. 1 page.

Woodling, J. 1985. Colorado's Little Fish: A Guide to the Minnows and Other Lesser Known Fishes in the State of Colorado. Colorado Division of Wildlife, Denver, Colorado. 77 pages.

Wortz, K. 2001. Personal communication [*June 21 telephone conversation with K. Mullins, Greystone, Greenwood Village, Colorado. RE:* City of Buffalo landfill]. City of Buffalo, Buffalo, Wyoming.

Wyoming Bioinformation Node (WBN). 2002. Black Hills redbelly snake. Located at http://www.wygisc.uwyo.edu/cgi-bin/wbn/atlas.cgi?ID=aradb34033&TYPE=map. Accessed July 26, 2002.

Wyoming Department of Employment. 1997a. Annual Average Employment and Wages for Converse, Johnson, Campbell, and Sheridan counties [Web Page]. Located at http://lmi.state.wy.us/facsdir/009.htm. Accessed May 15, 2001.

Wyoming Department of Employment. 1997b. Wyoming Total Wages, Average Weekly Wage and Annual Wages by Industry [Web Page]. Located at http://lmi.state.wy.us/97202pub/table12.htm.

Wyoming Department of Employment. 1997c. 1999 Wyoming Benchmark Labor Force Estimates [Web Page]. Located at http://lmi.state.wy.us/facsdir. Accessed May 15, 2001.

Wyoming Department of Employment. 2000. An Analysis of Growth in Housing Stock and Population 1990-2000 [Web Page]. Located at http://lmi.state.wy.us/0601/02.htm. Accessed July 2, 2002.

Wyoming Department of Employment Research and Planning. 2001a. Employment in Oil and Gas Extraction (SIC 13) by Year, Quarter and Selected Counties. 1 Page.

Wyoming Department of Employment Research and Planning. 2001b. Table 75. Sheridan county Northeast Region, Wyoming Average Employing Units, Average Monthly Employment, Total Payroll, and average Annual Wage by Major Industry & 2 Digits SIC, All Ownerships, 2000 [Web Page]. Located at http://lmi.state.wy.us/00202pub/sect75.htm. Accessed July 30, 2002.

Wyoming Department of Employment Research and Planning. 2002. Data and Presentation Prepared for the Powder River Coalbed Methane Information Council. June 7, 2002.

079

Wyoming Department of Environmental Quality. 2000. Wyoming's 2000 305(b) State Water Quality Assessment Report [Web Page]. Located at http://deq.state.wy.us/wqd/wtrshedpg.htm#Plan. Accessed: June 1, 2001.

Wyoming Department of Environmental Quality. 2001. NPDES Outfall Locations electronic file. Wyoming Department of Environmental Quality, Cheyenne, Wyoming.

Wyoming Department of Environmental Quality. 2002a. Wyoming's 2002 305(b)State Water Quality Assessment Report [Web Page]. Located at http://deq.state.wy.us/wqd/index.asp?pageid=50. Accessed on August 23, 2002.

Wyoming Department of Environmental Quality. 2002b. Wyoming's 2002 305(b) State Water Quality Assessment Report and 2002 303(d) List of Waters Requiring TMDLs [Web Page]. Located at http://deq.state.wy.us/wqd/Downloads/events/2-2226-doc.pdf. Accessed August 30, 2002.

Wyoming Department of Environmental Quality. 2002c. NPDES Outfall Locations electronic file. Wyoming Department of Environmental Quality, Cheyenne, Wyoming.

Wyoming Department of Revenue. 2000. Wyoming Department of Revenue records, for the State of Wyoming: Annual Report, July 1 1999 through June 30, 2000. Taxable Valuation of Mineral Production for Fiscal Year 1999. Wyoming Department of Revenue, Cheyenne, Wyoming.

Wyoming Department of Transportation. 1999. Vehicle Miles 1999. Wyoming Department of Transportation, Transportation Planning Program, Cheyenne, Wyoming.

Wyoming Department of Transportation. 2000. 2000 Surface Transportation Improvement Program. Wyoming Department of Transportation, Transportation Planning Program, Cheyenne, Wyoming.

Wyoming Division of Economic Analysis. 1997a. Wyoming Population Estimates and Forecasts for Counties, Cities, and Towns: 1990 to 2000 [Web Page]. Located at http://eadiv.state.wy.us/pop/wyc&sc90.htm. Accessed: August 21, 2001.

Wyoming Division of Economic Analysis. 1997b. Median household income [Web Page]. Located at http://eadiv.state.wy.us/demog_data/CNTY_INCOME79_99.htm. Accessed: May 31, 2001.

Wyoming Division of Economic Analysis. 1999. Equality State Almanac, 1998. State Park and Historic Site Visitors: 1994-1998 [Web Page]. Located at http://eadiv.state.wy.us/almanac/parks.htm. Accessed: August 7, 2001.

Wyoming Division of Economic Analysis. 2000a. Population Distribution by Race and Hispanic by County: 2000 [Web Page]. Located at http://

BEST COPY AVAILABLE

cadiv.state.wy.us/ demog_data/pop2000/cnty^sdis_00.htm. Accessed: May 16, 2001.

Wyoming Division of Economic Analysis. 2000b. Profiles of General Housing Characteristics by County and Places: 2000 [Web Page]. Located at http://eadiv.stat.wy.us/housing/HU_2000.htm. Accessed: July 30, 2002

Wyoming Division of Economic Analysis. 2000c. Census 2000 Housing Profiles [Web Page]. Located at http://eadiv.state.wy.us/housing/HU_2000.htm. Accessed: August 12, 2001.

Wyoming Division of Economic Analysis. 2001. Consensus Revenue Estimating Group, Natural gas, and Oil Revised January 9, 2001 [Web Page]. Located at http://eadiv.state.wy.us/creg/creg.htm. Accessed: August 10, 2001.

Wyoming Division of State Parks and Historic Sites. 2001. State Parks and Historic Sites Location [Web Page]. Located at http://spacr.state.wy.us/sphs/map.htm. Accessed: August 7, 2001.

Wyoming Emergency Management Agency. 2001a. 2001 Memorial Day Flood [Web Page]. Located at http://wema.state.wy.us/disasterhist.htm. Accessed: August 22, 2001.

Wyoming Emergency Management Agency. 2001b. Wyoming's Disaster History [Web Page]. Located at http://wema.state.wy.us/waters/2001flo[illegible]htm. Accessed: August 22, 2001.

Wyoming Game and Fish Department. 1997. Atlas of Birds, Mammals, Reptiles, and Amphibians in Wyoming. Wyoming Game and Fish Department, Non Game Program, Biological Services Section, Lander, Wyoming.

Wyoming Game and Fish Department. 2000a. Casper Region Annual Big Game Herd Unit Reports 2000. Cheyenne, Wyoming.

Wyoming Game and Fish Department (WGFD). 2000b. Sheridan Region Annual Big Game Herd Unit Reports 2000. Cheyenne, Wyoming.

Wyoming Game and Fish Department. 2001a. Big Game Harvest 2000 [Web Page]. Located at http://gf.state.wy.us/HTML/hunting/harvest.htm. Accessed: August 7, 2001.

Wyoming Game and Fish Department. 2001b. 2001 Walk-in Areas Fishing. [web Page]. Located at
http://gf.state.wy.us/html/pipw/fishingwalk/fishing.asp. Accessed: August 7, 2001.

Wyoming Game and Fish Department. 2002. Draft Wyoming Greater Sage-Grouse Conservation Plan. July 10, 2002. Located on the Internet at http://gf.state.wy.us/html/sagegrouse.htm. Accessed August 2, 2002.

Wyoming Office of State Lands and Investments. 1996. Final Report and Recommendations of the Select Committee on State Trust Lands. Office of State Lands and Investments, November 15, 1996. Wyoming Office of State Lands and Investments, Cheyenne, Wyoming

Wyoming Oil and Gas Conservation Commission. 1998. 1998 Wyoming Oil and Gas Statistics. Wyoming Oil and Gas Conservation Commission, Casper, Wyoming. 451 pages.

Wyoming Oil and Gas Conservation Commission. 2001a. 2000 Powder River Basin Production by Field [Web Page]. Located at http://wogcc.state.wy.us/Prodstats2.cfm. Accessed: August 15, 2001.

Wyoming Oil and Gas Conservation Commission. 2001b. 2000 Water Production — CBM Wells. Wyoming Oil and Gas Conservation Commission, Casper, Wyoming.

Wyoming Oil and Gas Conservation Commission. 2001c. Personal communication. [*August* e-mail to C. Florian, Greystone, Greenwood Village, Colorado. *RE*: 2000 CBM Water Production].

Wyoming Oil and Gas Conservation Commission. 2001d. Well Information — Non-CBM Wells. Wyoming Oil and Gas Conservation Commission, Casper, Wyoming.

Wyoming Oil and Gas Conservation Commission. 2002a. 2001 Water Disposal Wells. Wyoming Oil and Gas Conservation Commission, Casper, Wyoming.

Wyoming Oil and Gas Conservation Commission. 2002b. 2001 Water Production – CBM Wells. Wyoming Oil and Gas Conservation Commission, Casper, Wyoming.

Wyoming Partnership Database. 2002. Wyoming Housing Conditions, Table I.11 Average Sales Prices Reported by Assessors. [Web Page]. Located at http://www.wyomingcda.com. Accessed: July 31, 2002.

Wyoming State Engineer's Office. 2001a. Groundwater Rights electronic file. Wyoming State Engineer's Office, Cheyenne, Wyoming.

Wyoming State Engineer's Office. 2001b. Personal communication. [*May* e-mail to C. Womack, Greystone, Greenwood Village, Colorado. *RE*: Surface Water Rights Search]. Wyoming State Engineer's Office, Cheyenne, Wyoming.

Wyoming State Engineer's Office. 2001c. Surface Water Rights electronic file. Wyoming State Engineer's Office, Cheyenne, Wyoming.

Wyoming State Engineer's Office. 2002. Groundwater Rights in Campbell, Converse, Johnson, and Sheridan Counties, Facility Name – Spring, Groundwater Rights Database. WSEO Homepage: http://seo.state.wy.us Accessed on: 8/19/02.

Wyoming State Geological Survey. 2001. August 8, 2000 — Coalbed Methane Resources in Powder River Basin More Than Doubled [Web Page]. Located at http://www.wsgsweb.uwyo.edu/pressrel/aug10-a.html. Accessed: August 22, 2001.

Wyoming State Geological Survey. 2002. Personal communication [*March 7* written communication to A. Reese, Wyoming Office of Federal Land Policy, Cheyenne, Wyoming *RE*: Powder River Basin Oil and Gas Draft EIS] Wyoming State Geological Survey, Laramie, Wyoming.Wyoming Water Resources Center. 1997. A Study of Techniques to Assess Surface and Groundwater Impacts Associated with Coal Bed methane and Surface Goal Mining. Unpublished report. Wyoming Water Resources Center.

Wyoming Water Resources Data System (WRDS). 2001a. Earthquakes in Wyoming [Web Page]. Located at: http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/quake.html. Accessed: August 22, 2001.

Wyoming Water Resources Data System. 2001b. Landslides in Wyoming [Web Page]. Located at http://www.wrds.uwyo.edu/wrds/wsgs/hazards/landslides/lshome.html. Accessed: August 22, 2001.

Wyoming Water Resources Data System. 2002. Water Quality Data for Springs. Water Quality Database. WRDS Homepage: http://www.wrds.uwyo.edu/ Accessed on: August 16, 2002.

Yaeger, M. 1998. American Bittern. Pages 52-53 *in*: Kingery, H.E., ed. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife. Denver, Colorado.

Yarmoloy, C., M. Bayer, and V. Geist. 1988. Behavior responses and reproduction of mule deer does following experimental harassment with an all-terrain vehicle. Canadian Field Naturalist 102(3): 425-429.

Yingling, Rob 2001. Personal communication. [*May 24* telephone conversation with K. Cloutier, Greystone Environmental Consultants, Greenwood Village, Colorado. *RE*: Information on Johnson County planning and zoning]. County Planner, Johnson County Planning Department, Buffalo, Wyoming.

Zavadil, D. 2001. Personal communication [*December 4* telephone conversation K. Mullins. Greystone Environmental Consultants, Greenwood Village, Colorado. *RE*: Typical cost information on reclamation and water handling methods as well as energy costs typically associated with gas and electric compression]. Environmental Manager, Williams Production, Denver, Colorado. 2 pages.

Zelt, R. B., G. Boughton, K. A. Miller, J. P. Mason, and L. M. Gianakos. 1999. Environmental Setting of the Yellowstone River Basin, Montana, North Dakota, and Wyoming. U.S. Geological Survey Water-Resources Investigations Report 98-4269. 113 pages.

Zeveloff, S. I., and F. R. Collett. 1988. Mammals of the Intermountain West. University of Utah Press, Salt Lake City.

Zinn, J.A. and C. Copeland. 2001. Wetland Issues. Congressional Research Service Issue Brief. Publication IB97014. Resources, Science, and Industry Division, Washington, DC. March 14. 12 pages.

Zweig, L.D. and C.F. Rabeni. 2001. Biomonitoring for deposited sediment using benthic macroinvertebrates: a test on four Missouri streams. J. N. Amer. Benthol. Soc. 20: 643-657.

475

BLANK PAGE

Index

BEST COPY AVAILABLE

BLANK PAGE

Index

A

Access road.... 1–8, 1–11, 2–10, 2–21, 2–23, 2–25, 2–33, 2–38, 2–40, 2–42, 2–60, 3–81, 3–262, 4–127, 4–131, 4–140, 4–264, 4–291, 4–300, 4–308, 4–313, 4–314, 4–315, 4–317, 4–318, 4–319, 4–320, 4–321, 4–328, 4–330, 4–359, 4–360, 4–394, 4–395, 4–400, 4–422, 4–426
Agriculture....... 2–7, 3–49, 3–72, 3–80, 3–88, 3–96, 3–110, 3–118, 3–147, 3–156, 3–160, 3–176, 3–208, 3–258, 3-299, 3-300, 4–72, 4–74, 4–89, 4–107, 4–108, 4–115, 4–158, 4–172, 4–185, 4–187, 4–220, 4–230, 4–234, 4–244, 4–257, 4–284, 4–286, 4–355, 9–11
Authorizing Officer..9–2

B

Badlands National Park 3–310, 4–410

C

Carbon monoxide..........................3-306, 4–401, 4–402, 4–403, 4–404, 4–405, 9–4
Criteria Pollutant...9–4
Crow Indian Reservation 3–310, 4–402, 4–403, 4–404, 4–405

D

Dry Creek Petrified Tree Environmental Education Area...... 3–254, 3-279, 3-281, 3-282

E

Earthquake (seismic activity)..3–73, 9–6, 10–33, 10-41

F

Federal Land Policy and Management Act (FLPMA) 1–2, 1–6, 3–181, 4–397, 5–1
Floodplain...9–8, 10–17
Fortification Creek Area 3–138, 3-282, 3-283
Fugitive dust 4–396, 4–400, 4–426

G

Grassland ....1–1, 3–187, 3–188, 3-276, 3-283, 4–327, 5–2, [illegible]
Grazing 3–111, 3–114, 3–256, 3–282, 7–1, 7–2

H

Hunting 3-276, 3-277, 4–191, 4–342, 4–343

483

BLANK PAGE

I

Interstate 25 ....3–258, 3–275, 4–142, 4–156, 4–[illegible], 4–343, 4–372
Interstate 90 ......3–21, 3–175, 3–262, 3–264, 3–275, 3–280, 4–314, 4–325, 4–372, 4–422

M

Medicine Bow-Routt National Forest.........1–7, 3–239, 3–255, 3–269, 3–283, 5–3, 10–40
Mosier Gulch Recreation Area 3–254, 3–280, 3–281, 3–282

N

Native American......2–6, 2–8, 3–223, 3–227, 3–238, 3–288, 3–300, 4–287, 4–288, 4–290, 4–291, 4–375, 4–387, 9–4
Nitrogen oxides..............3–305, 3–306, 4–399, 4–401, 4–403, 4–404, 4–405, 4–423, 4–424, 9–4
Northern Cheyenne Indian Reservation..........................2–7, 3–300, 3–301, 3–309
Noxious weed 2–40, 3–107, 3–108, 4–168, 4–187

O

Onshore Oil and Gas Order 1–8, 1–9, 2–23, 2–43
OSHA 4–388

P

PM$_{10}$......... 2–77, 2–84, 3–305, 3–306, 3–308, 3–312, 3–313, 4–396, 4–397, 4–398, 4–399, 4–401, 4–402, 4–403, 4–404, 4–405, 4–406, 4–424, 9–4, 9–13, 10–26

R

Resource Management Plan............................. 1–5, 1–6, 1–7, 4–326, 5–1, 5–2, 5–4
Royalty... 1–6, 4–362, 4–363, 4–366, 4–367, 4–379

S

SAR2–4, 2–82, 3–7, 3–8, 3–10, 3–11, 3–14, 3–15, 3–16, 3–17, 3–49, 3–50, 3–51, 3–58, 3–87, 3–88, 4–72, 4–73, 4–74, 4–75, 4–76, 4–77, 4–78, 4–80, 4–81, 4–82, 4–83, 4–84, 4–86, 4–88, 4–89, 4–91, 4–92, 4–93, 4–94, 4–95, 4–96, 4–97, 4–98, 4–101, 4–106, 4–107, 4–108, 4–110, 4–113, 4–114, 4–115, 4–118, 4–122, 4–125, 4–151, 4–153, 4–154, 4–155, 4–158, 4–307, 4–308, 4–388, 4–391, 10–22
Scenic byway 3–258
South Big Horns Area.......................................3–263, 3–276, 3–280, 3–281, 3–282
Spring.... 3–10, 3–70, 3–119, 3–121, 3–125, 3–126, 3–132, 3–136, 3–137, 3–140, 3–143, 3–144, 3–145, 3–146, 3–205, 4–125, 4–130, 4–197, 4–198, 4–200, 4–201, 4–208, 4–209, 4–211, 4–212, 4–213, 4–214, 4–217, 4–218, 10–47

T

Tax revenue 4–378, 4–379, 4–381

Thunder Basin National Grassland ... 1–1, 1–5, 1–6, 1–7, 2–44, 2–45, 2–71, 2–90, 3–188, 3–239, 3–253, 3–255, 3–269, 3-274, 3-281, 3-282, 3-283, 3-284, 4–327, 5–2, 5–3, 5–4, 5–5
Total dissolved solids 3–7, 3–9, 3–10, 3–11, 3–12, 3–14, 3–49, 3–52, 3–83, 3–87, 3–173, 4–55, 4–69, 4–72, 4–129, 4–134, 4–151, 4–153, 4–158, 4–185, 4–249, 4–258, 4–416
Traffic 3–259, 3–261, 4–159, 4–261, 4–337, 4–372, 4–394, 10–12

U

U.S. Environmental Protection Agency... ...2–30, 2–31, 3–11, 3–12, 3–13, 3–14, 3–50, 3–54, 3–73, 3–77, 3–78, 3–160, 3–310, 3–312, 3–313, 4–58, 4–59, 4–72, 4–73, 4–74, 4–97, 4–103, 4–107, 4–114, 4–122, 4–123, 4–153, 4–154, 4–247, 4–249, 4–251, 4–307, 4–348, 4–350, 4–375, 4–376, 4–384, 4–385, 4–388, 4–390, 4–392, 4–394, 4–396, 4–397, 4–398, 4–400, 4–401, 4–405, 4–408, 4–410, 4–411, 4–423, 8–1, 10–1, 10–3, 10–14, 10–37, 10–38
U.S. Fish and Wildlife Service 3–50, 3–112, 3–160, 3–173, 3–179, 3–180, 3–181, 3–182, 3–183, 3–184, 3–185, 3–186, 3–187, 3–188, 3–191, 3–194, 3–195, 3–196, 3–197, 3–201, 3–202, 3–210, 3–211, 3–214, 4–260, 4–261, 4–263, 4–286, 4–407, 4–408, 4–418, 4–419, 4–420, 4–421, 10–39
U.S. Highway 16..3-281

V

Visual Resource Management 3–263, 3–266, 9–19

W

Watershed 3–31, 3–42, 3–43, 3–51, 3–55, 3–160, 3–243, 3–244, 3-278, 3-279, 4–75, 4–80, 4–81, 4–83, 4–85, 4–86, 4–88, 4–90, 4–92, 4–94, 4–96, 4–100, 4–101, 4–102, 4–103, 4–105, 4–106, 4–109, 4–110, 4–111, 4–112, 4–113, 4–117, 4–118, 4–119, 4–120, 4–153, 4–189, 4–308, 4–324, 4–332, 4–333, 4–334, 4–335, 4–345, 4–375, 7–5, 9–19, 10–38
Weston Hill Recreation Area...3-282, 4–326, 4–345
Wetland.. 4–180, 4–415, 4–425, 10–14, 10–19, 10–48
Wind Cave National Park 2–85, 3–309, 4–410, 4–411
Winter range 3–194
Wyoming Department of Environmental Quality....... 1–6, 2–2, 2–26, 2–29, 2–30, 2–32, 2–38, 2–48, 2–49, 2–76, 2–77, 3–8, 3–14, 3–44, 3–45, 3–50, 3–52, 3–53, 3–56, 3–110, 3–115, 3-305, 4–10, 4–62, 4–72, 4–74, 4–75, 4–78, 4–81, 4–82, 4–83, 4–84, 4–86, 4–87, 4–89, 4–91, 4–93, 4–97, 4–108, 4–121, 4–124, 4–125, 4–126, 4–127, 4–129, 4–141, 4–178, 4–235, 4–244, 4–248, 4–251, 4–258, 4–375, 4–397, 4–398, 4–409, 4–423, 10–7
Wyoming Game and Fish Department ... 3–93, 3–95, 3–96, 3–102, 3–103, 3–104, 3–105, 3–106, 3–107, 3–110, 3–111, 3–119, 3–120, 3–125, 3–127, 3–128, 3–131, 3–136, 3–138, 3–144, 3–145, 3–147, 3–155, 3–160, 3–161, 3–167, 3–173, 3–178, 3–179, 3–182, 3–184, 3–194, 3–203, 3–204, 3–205, 3–208, 3–210, 3–211, 3–255, 3-277, 3-278, 4–191, 4–266, 4–267, 4–268, 4–269, 4–270, 4–271, 4–272, 4–273, 4–274, 4–275, 4–276, 4–277, 4–278, 4–279, 4–282, 4–285, 4–343, 10–46

485

Wyoming Oil and Gas Conservation Commission... 1–6, 2–23, 2–25, 2–26, 2–29, 2–30, 2–32, 2–43, 2–45, 2–46, 2–48, 2–50, 2–51, 2–59, 3–8, 3–31, 3–56, 3–57, 3–71, 3–257, 4–10, 4–11, 4–55, 4–58, 4–62, 4–76, 4–78, 4–124, 4–125, 4–126, 4–127, 4–135, 4–138, 4–392

☆ U.S. GOVERNMENT PRINTING OFFICE: 2002 — 573-082 / 40016 Region No. 8

486

BLANK PAGE

END

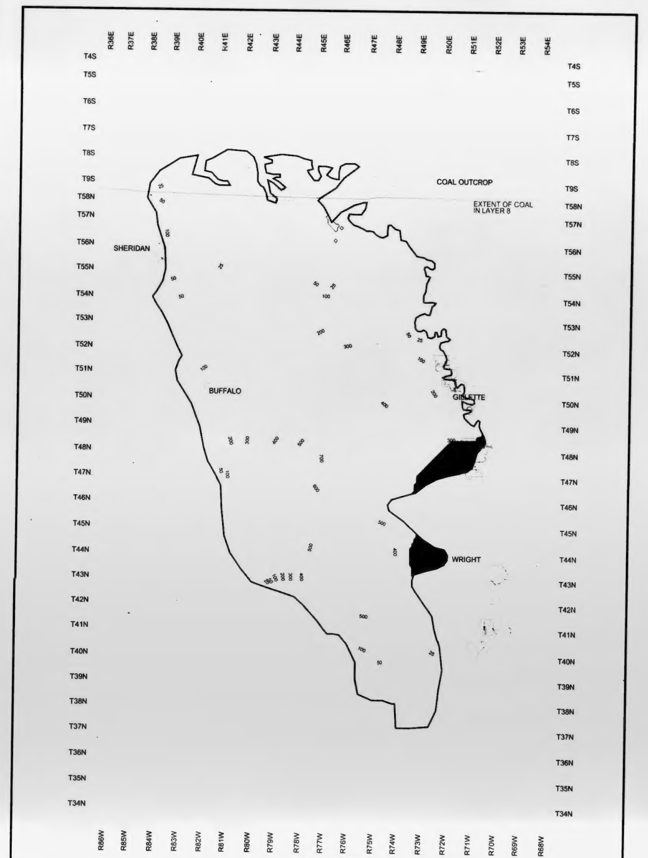
DATE FILMED

9 / 21 / 04

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

08 OF 34
12.5X
SUPTDOCS/GPO
MAP 1


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S
T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 8
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
25
50
100
200
300
400
500
600
700
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W

FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

T COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 8
▪ Dry Cell
Towns
Mine Boundary

N

0 7.5 15 30 Miles

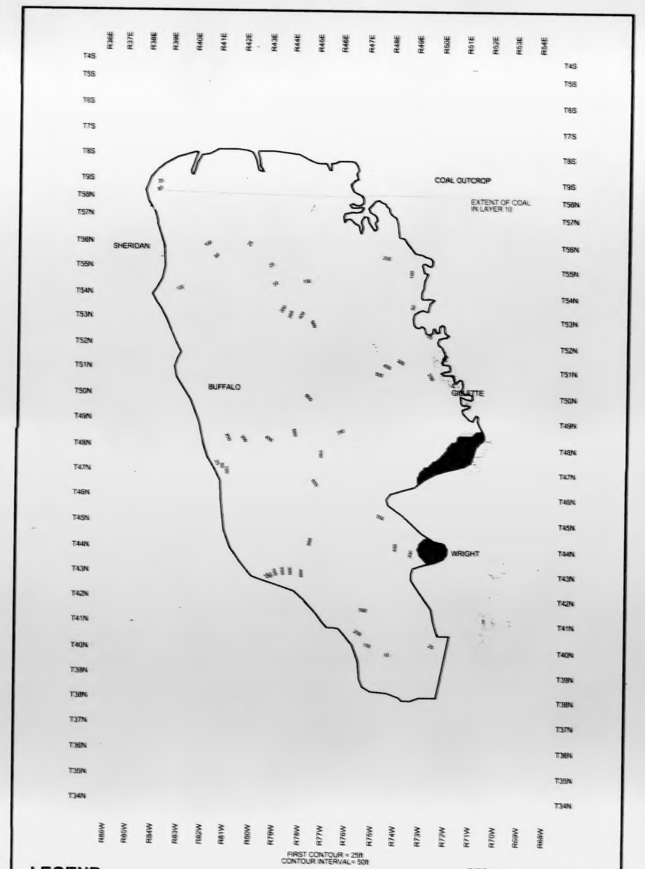
Note: Contours are not closed due to insufficient data.

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-2
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 8 YEAR 2006*

MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 4-2_4-5.dwg
Scale: As Noted	Drawn By: ETC

1


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 10
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
FIRST CONTOUR = 25ft
CONTOUR INTERVAL = 50ft
N
0 7.5 15 30 Miles

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 10
▨ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

BEST COPY AVAILABLE

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-3
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2006

MODEL RUN: From 1999-2200 (08-28-02)

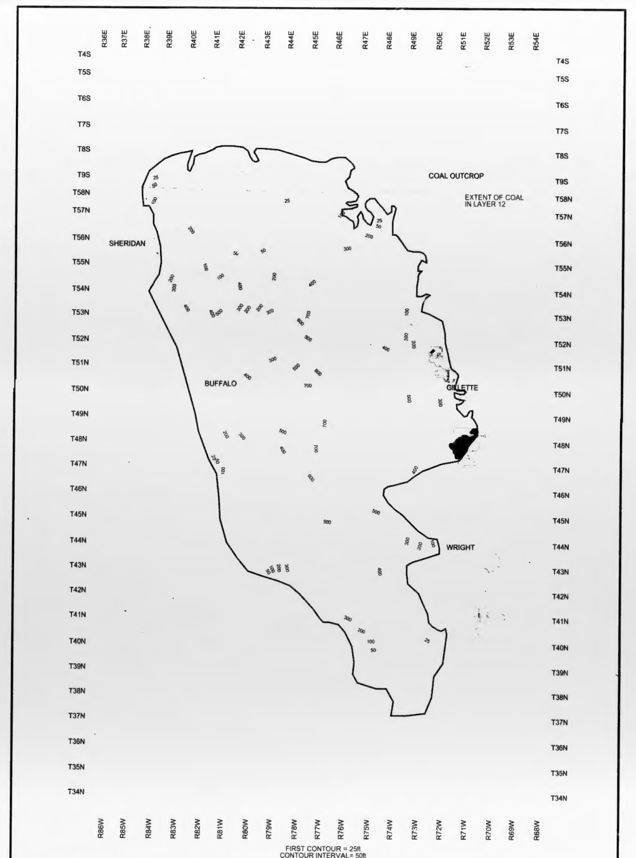
Date: 09/05/02	Drawing File: Figure 4-2_4-5.dwg
Scale: As Noted	Drawn By: ETC

2

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

10 OF 34
12.5X
SUPTDOCS/GPO
MAP 3



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
■ Dry Cell
Towns
Mine Boundary

N

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

BEST COPY AVAILABLE

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

FIGURE 4-4
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2006

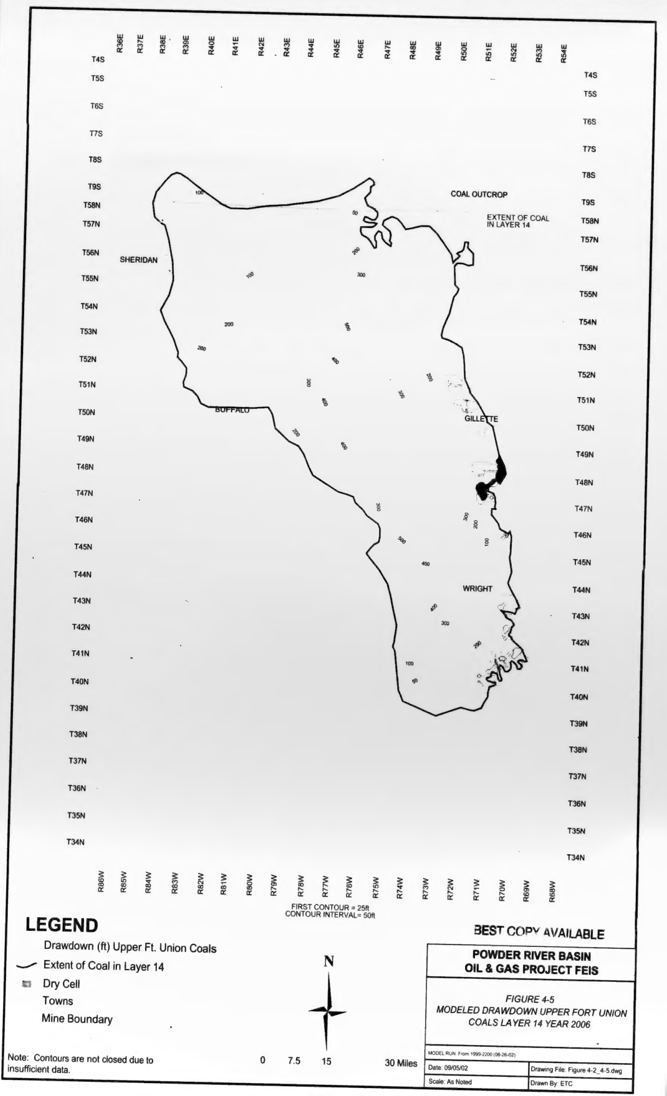
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 4-2_4-5.dwg
Scale: As Noted	Drawn By: ETC

3

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

11 OF 34
12.5X
SUPTDOCS/GPO
MAP 4



Note: Contours are not closed due to insufficient data.

BEST COPY AVAILABLE

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-5
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 14 YEAR 2006*

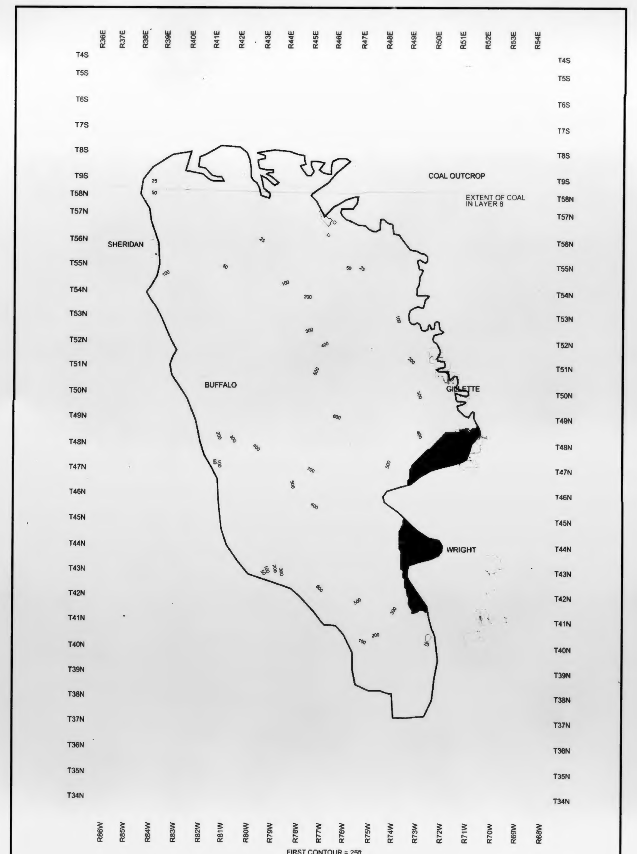
MODEL RUN From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-2_4-5.dwg
Scale: As Noted
Drawn By: ETC

4

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

12 OF 34
12.5X
SUPTDOCS/GPO
MAP 5


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S
T5S
T6S
T7S
T8S
T9S
T58N
T57N
T56N
T55N
T54N
T53N
T52N
T51N
T50N
T49N
T48N
T47N
T46N
T45N
T44N
T43N
T42N
T41N
T40N
T39N
T38N
T37N
T36N
T35N
T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 8
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
25
50
100
200
300
400
500
600
700
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W

FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 8
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-6
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 8 YEAR 2009*

MODEL RUN From 1999-2200 (08-26-02)

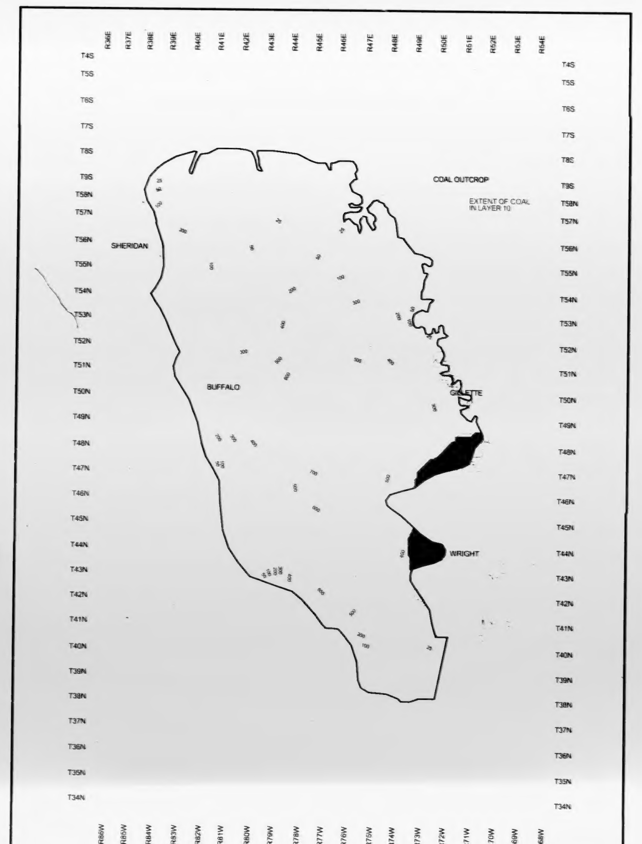
Date: 09/05/02	Drawing File: Figure 4-6_4-9.dwg
Scale: As Noted	Drawn By: ETC

5

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

13 OF 34
12.5X
SUPTDOCS/GPO
MAP 6


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 10
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 10
▪ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

BEST COPY AVAILABLE

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-7
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2009*

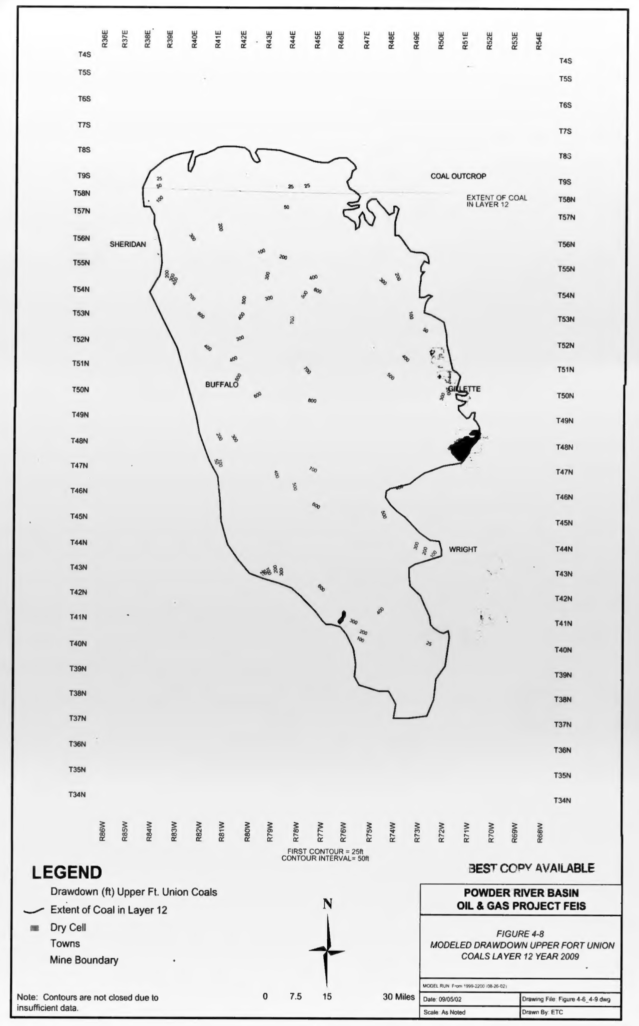
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 4-6_4-9.dwg
Scale: As Noted	Drawn By: ETC

6

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

14 OF 34
12.5X
SUPTDOCS/GPO
MAP 7


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 12
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft
LEGEND
Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
Dry Cell
Towns
Mine Boundary
N
0 7.5 15 30 Miles
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-6_4-9.dwg
Scale: As Noted
Drawn By: ETC

Note: Contours are not closed due to insufficient data.

BEST COPY AVAILABLE

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

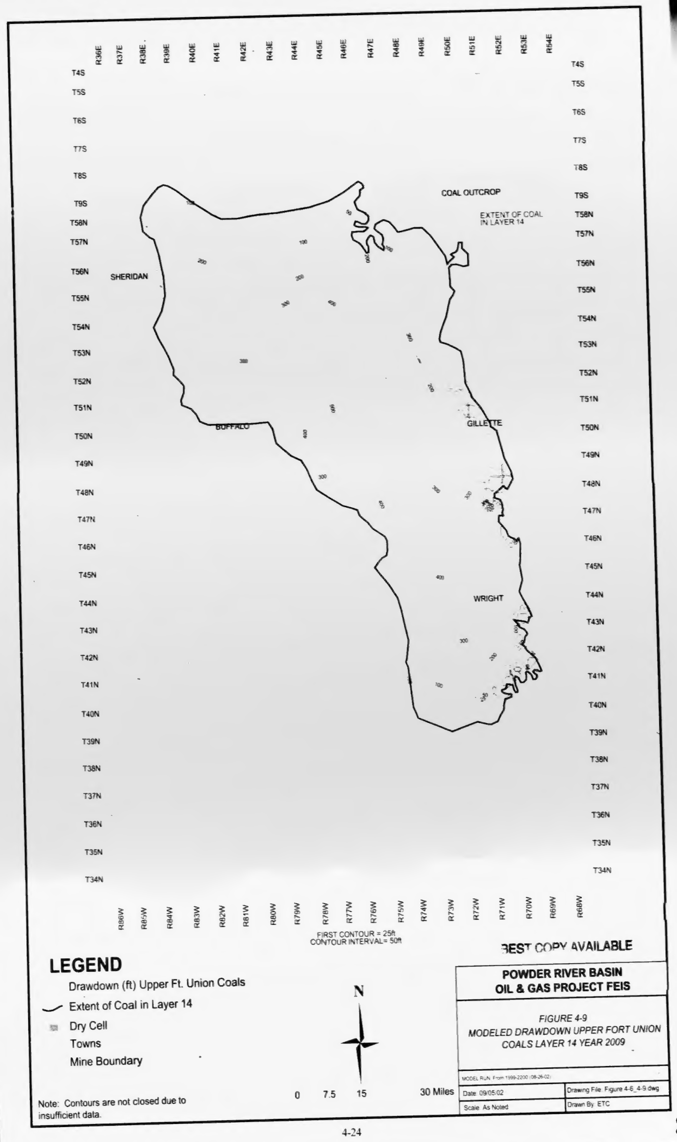
FIGURE 4-8
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2009

7

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

I 53.59:P
87/2/FINAL/V.2

15 OF 34
12.5X
SUPTDOCS/GPO
MAP 8



BEST COPY AVAILABLE

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-9
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 14 YEAR 2009*

MODEL RUN: From 1999-2200 (08-26-02)

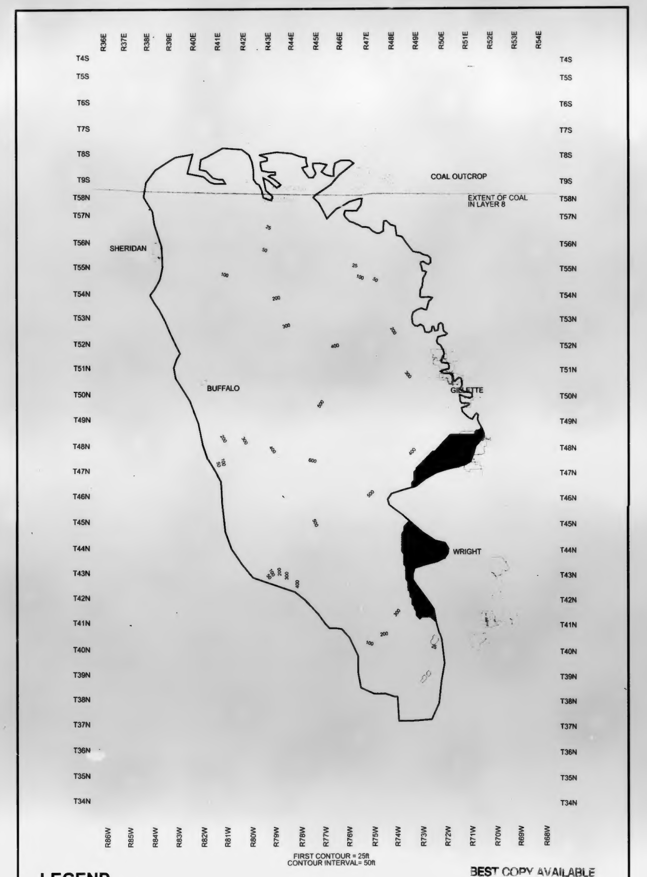
Date: 09/05/02	Drawing File: Figure 4-6_4-9.dwg
Scale: As Noted	Drawn By: ETC

8

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

I 53.59:P
87/2/FINAL/V.2

16 OF 34
12.5X
SUPTDOCS/GPO
MAP 9


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S
T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 8
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
25
50
100
200
300
400
500
600
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
⌒ Extent of Coal in Layer 8
■ Dry Cell
Towns
Mine Boundary

N

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

FIGURE 4-10
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2012

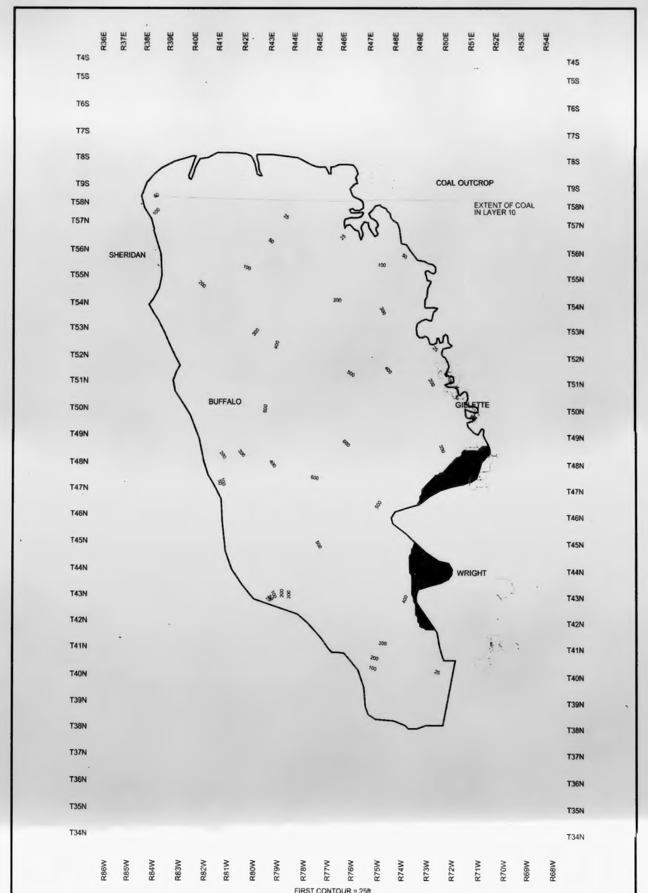
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 4-10_4-13.dwg
Scale: As Noted	Drawn By: ETC

9

FINAL ENVIRONMENTAL IMPACT STATEMENT AND PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING STATE OFFICE... BUREAU OF LAND MANAGEMENT... U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

I 53.59:P
87/2/FINAL/V.2

17 OF 34
12.5X
SUPTDOCS/GPO
MAP 10



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 10
▨ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-11
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2012

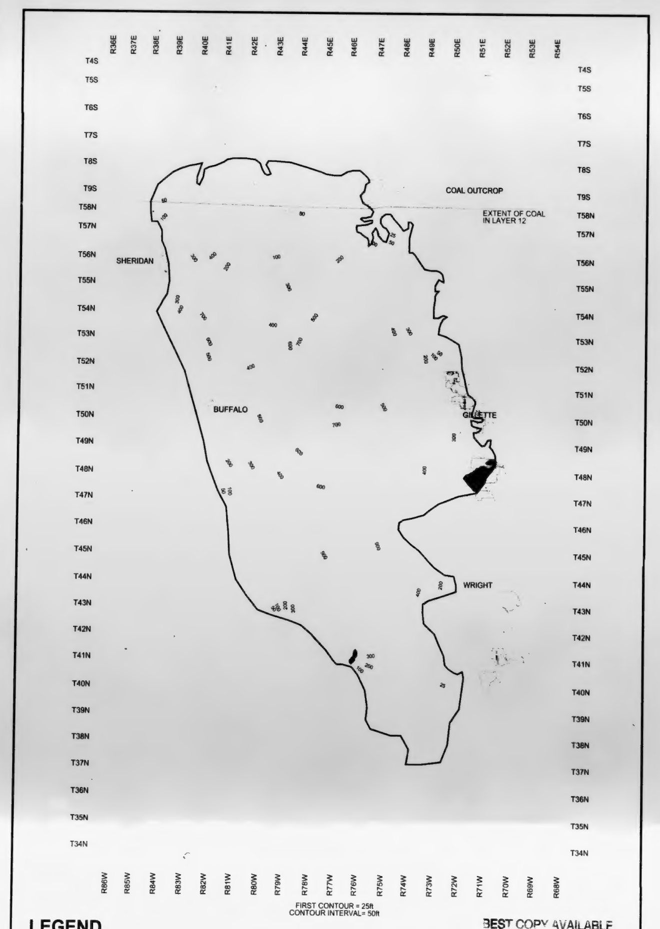
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 4-10_4-13.dwg
Scale: As Noted	Drawn By: ETC

10

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

18 OF 34
12.5X
SUPTDOCS/GPO
MAP 11



BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-12
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2012

MODEL RUN: From 1999-2200 (08-26-02)

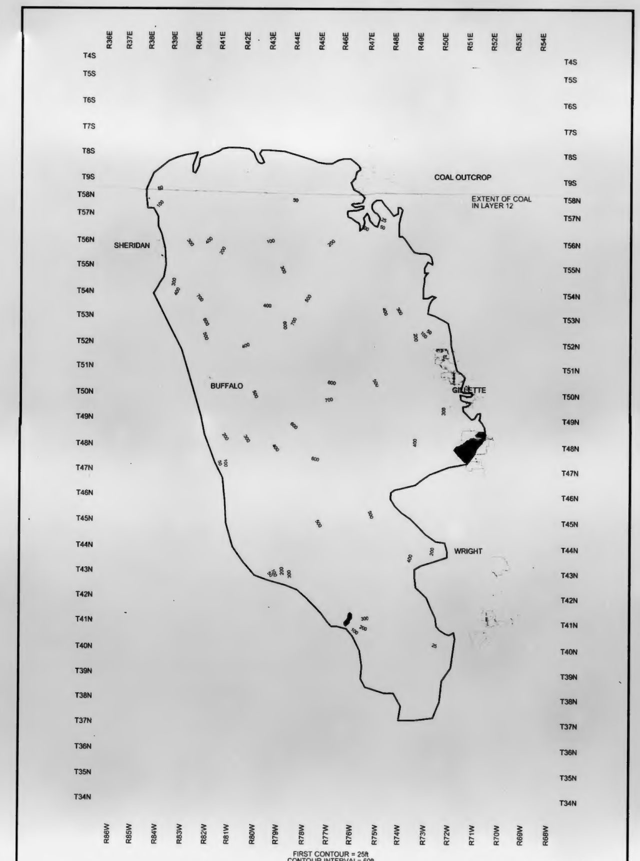
Date: 09/05/02	Drawing File: Figure 4-10_4-13.dwg
Scale: As Noted	Drawn By: ETC

11

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

19 OF 34
12.5X
SUPTDOCS/GPO
MAP 12



BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-12
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2012

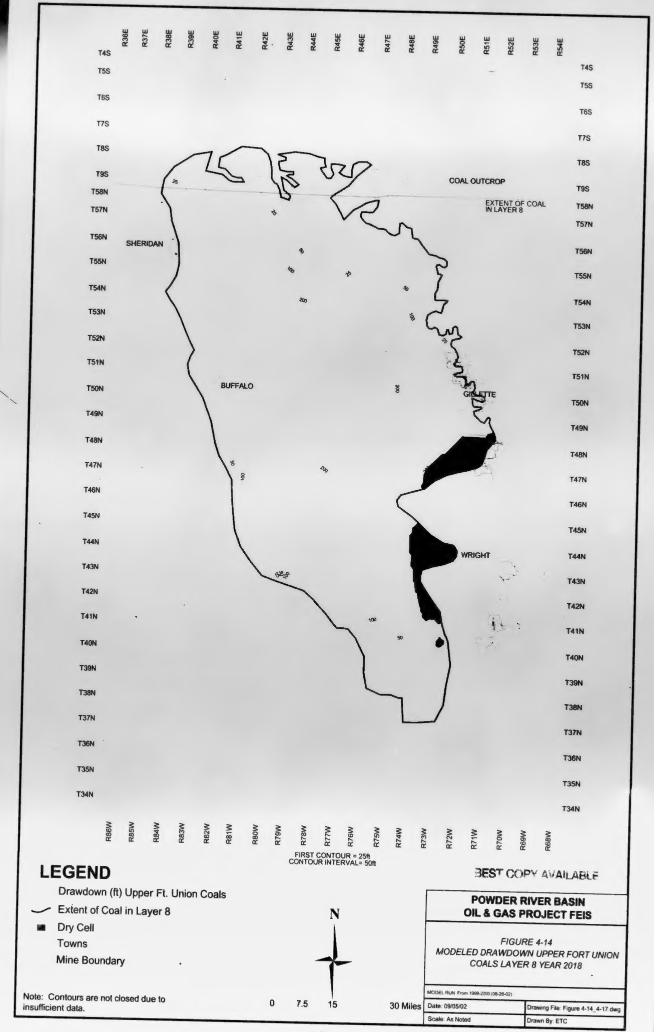
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-10_4-13.dwg
Scale: As Noted
Drawn By: ETC

11

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

20 OF 34
12.5X
SUPTDOCS/GPO
MAP 13



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 8
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-14
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 8 YEAR 2018*

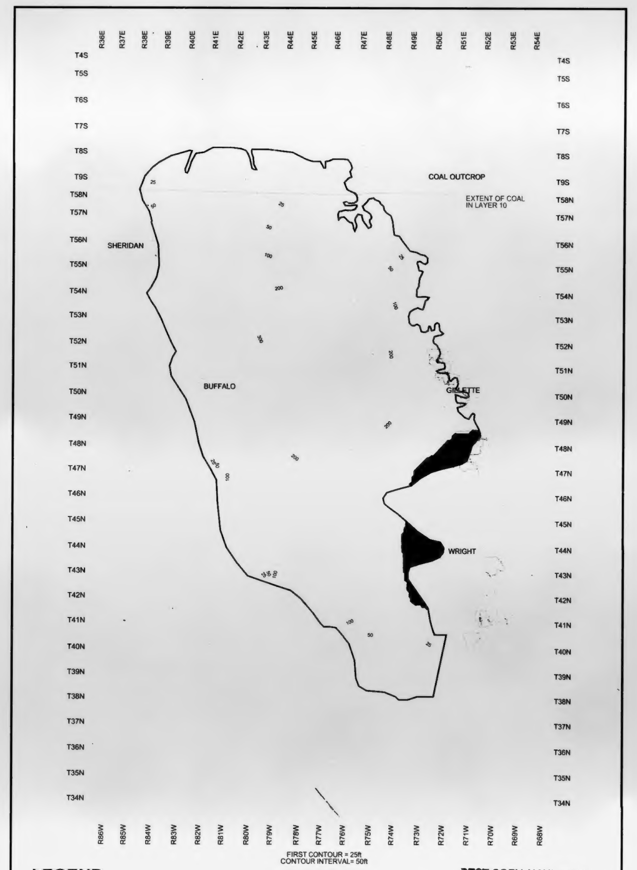
MODEL RUN From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-14_4-17.dwg
Scale: As Noted
Drawn By: ETC

13

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

21 OF 34
12.5X
SUPTDOCS/GPO
MAP 14


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
COAL OUTCROP
EXTENT OF COAL IN LAYER 10
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
25
50
100
200
300

FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 10
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-15
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 10 YEAR 2018*

MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-14_4-17.dwg
Scale: As Noted
Drawn By: ETC

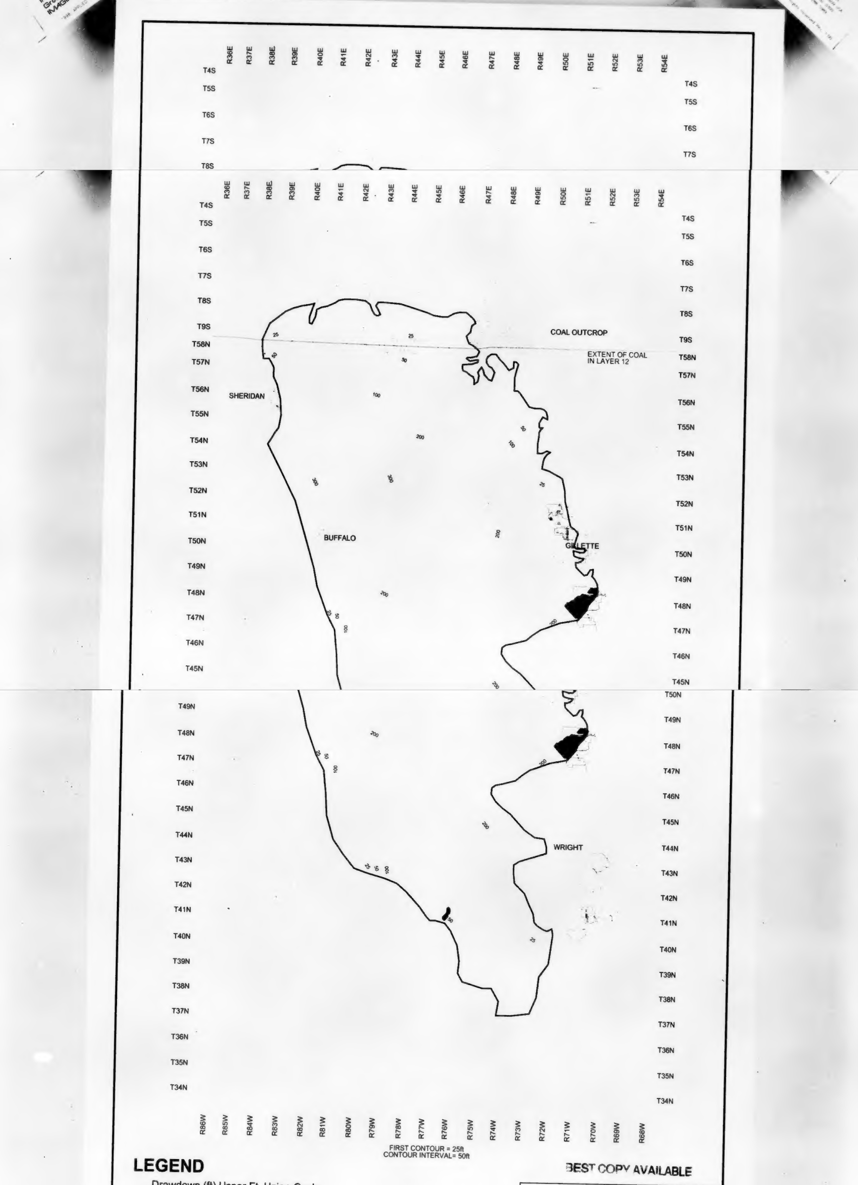
14

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

22 OF 34
12.5X
SUPTDOCS/GPO
MAP 15

87/2/FINAL/V.2
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003
MAP 15



LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

BEST COPY AVAILABLE

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

FIGURE 4-16
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2018

MODEL RUN: From 1999-2200 (08-26-02)

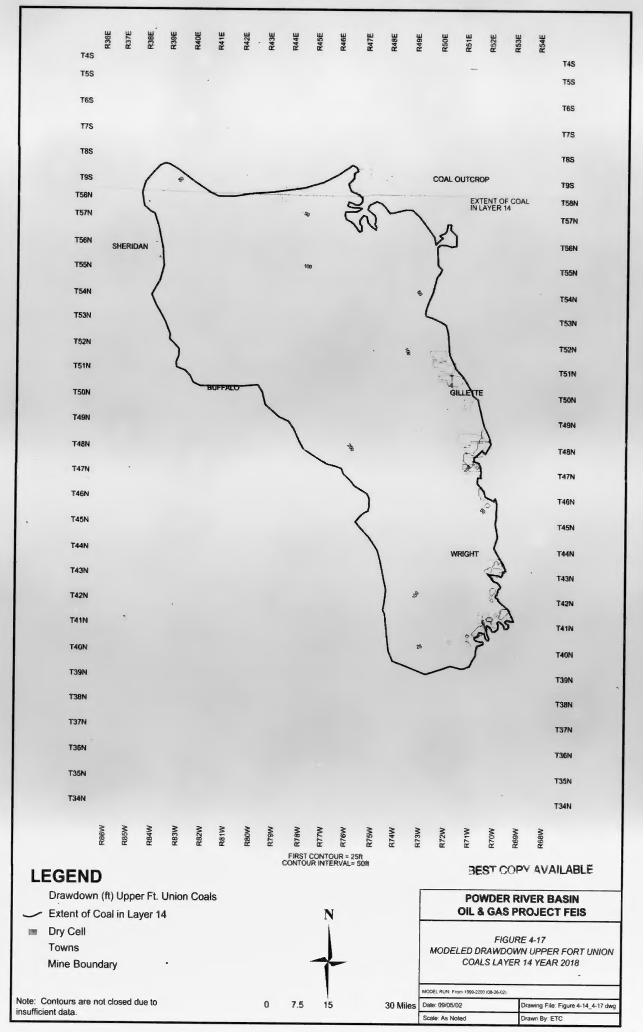
Date: 09/05/02	Drawing File: Figure 4-14_4-17.dwg
Scale: As Noted	Drawn By: ETC

15

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

23 OF 34
12.5X
SUPTDOCS/GPO
MAP 16



Note: Contours are not closed due to insufficient data.

BEST COPY AVAILABLE

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

FIGURE 4-17
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2018

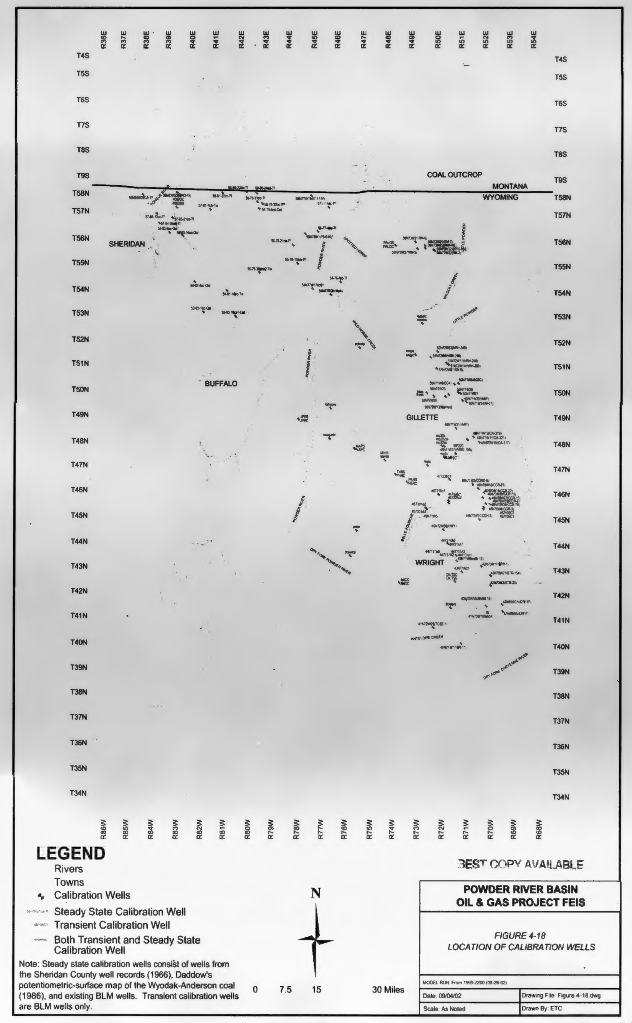
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-14_4-17.dwg
Scale: As Noted
Drawn By: ETC

16

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

24 OF 34
12.5X
SUPTDOCS/GPO
MAP 17



LEGEND

- Rivers
- Towns
- Calibration Wells
- Steady State Calibration Well
- Transient Calibration Well
- Both Transient and Steady State Calibration Well

Note: Steady state calibration wells consist of wells from the Sheridan County well records (1966), Daddow's potentiometric-surface map of the Wyodak-Anderson coal (1986), and existing BLM wells. Transient calibration wells are BLM wells only.

BEST COPY AVAILABLE

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-18
LOCATION OF CALIBRATION WELLS*

MODEL RUN From 1999-2200 (08-26-02)

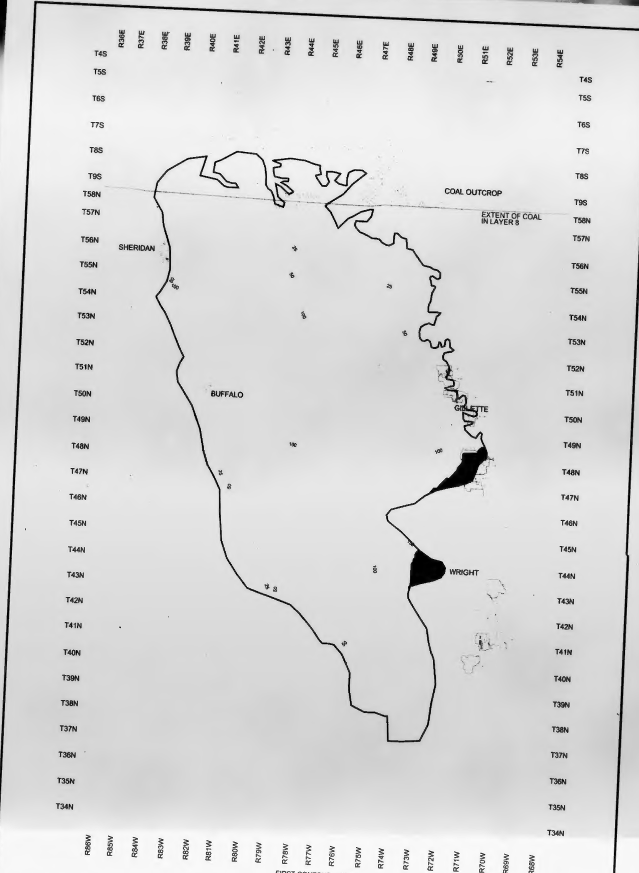
Date: 09/04/02	Drawing File: Figure 4-18.dwg
Scale: As Noted	Drawn By: ETC

17

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND PROPOSED PLAN....VOLUME 2 OF 4... WYOMING STATE OFFICE... BUREAU OF LAND MANAGEMENT... U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

25 OF 34
12.5X
SUPTDOCS/GPO
MAP 18



BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 8
■ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-22
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2030

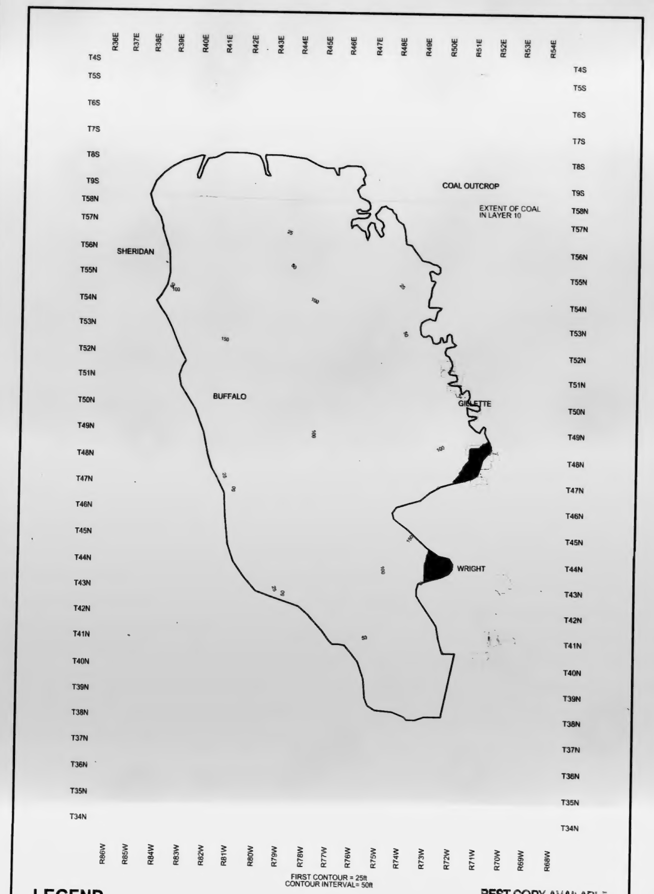
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02 | Drawing File: Figure 4-22_4-25.dwg
Scale: As Noted | Drawn By: ETC

18

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

26 OF 34
12.5X
SUPTDOCS/GPO
MAP 19



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals

Extent of Coal in Layer 10

■ Dry Cell

Towns

Mine Boundary

N

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-23
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2030

MODEL RUN: From 1999-2200 (08-26-02)

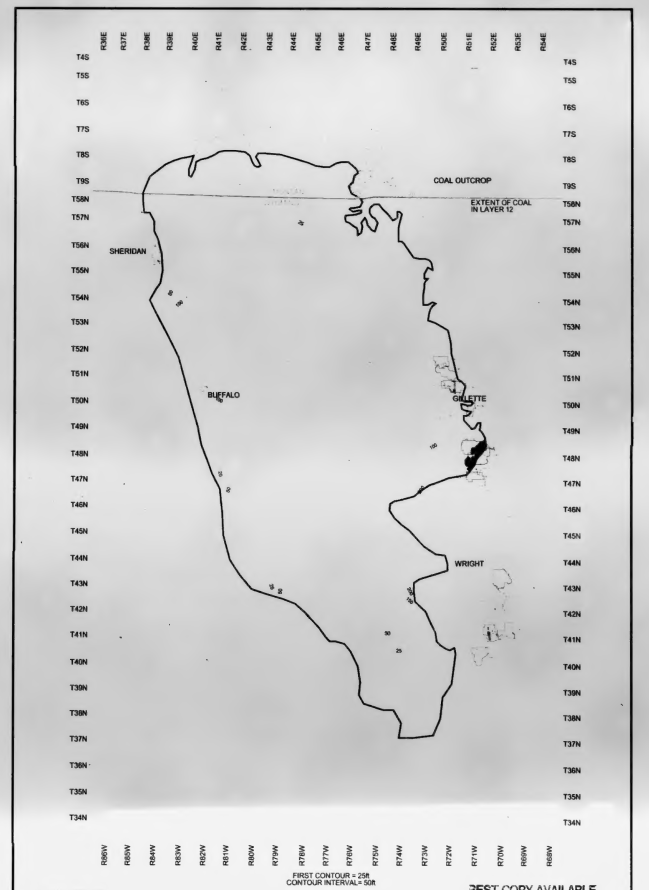
Date: 09/05/02	Drawing File: Figure 4-22_4-25.dwg
Scale: As Noted	Drawn By: ETC

19

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

27 OF 34
12.5X
SUPTDOCS/GPO
MAP 20



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
■ Dry Cell
Towns
Mine Boundary

N

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-24
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2030

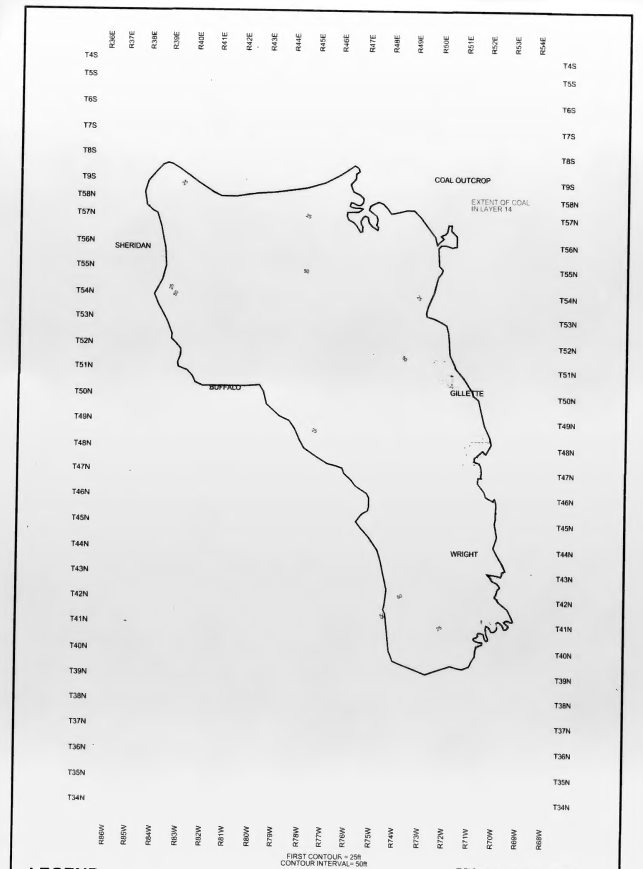
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 4-22_4-25.dwg
Scale: As Noted
Drawn By: ETC

20

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

28 OF 34
12.5X
SUPTDOCS/GPO
MAP 21



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

BEST COPY AVAILABLE

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 14
- ▨ Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

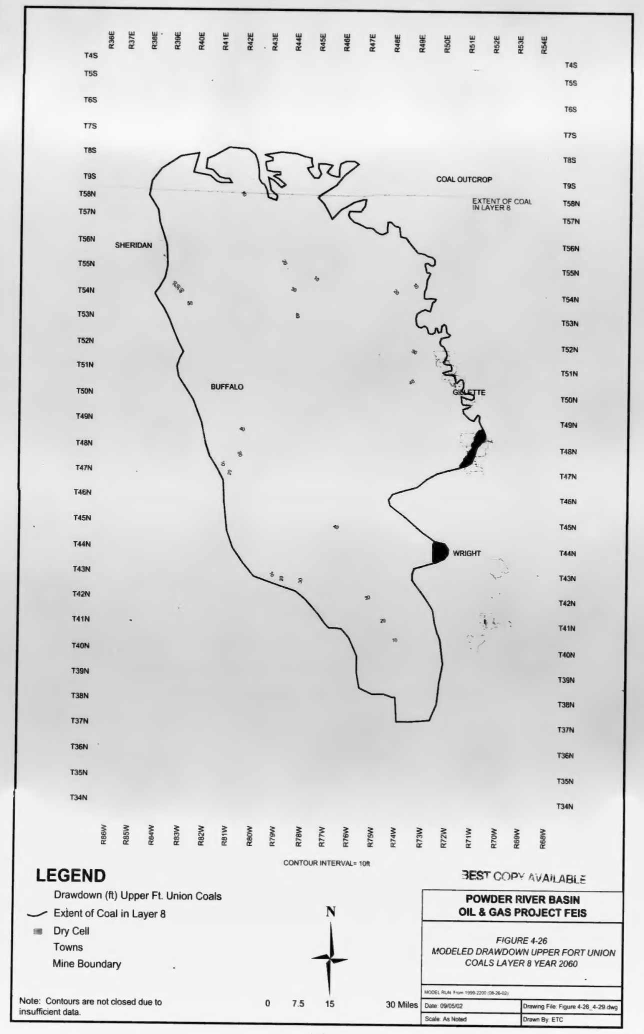
*FIGURE 4-25
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 14 YEAR 2030*

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 4-22_4-25.dwg
Scale: As Noted	Drawn By: ETC

21

I 53.59:P
87/2/FINAL/V.2



Note: Contours are not closed due to insufficient data.

BEST COPY AVAILABLE

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-26
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 8 YEAR 2060*

MODEL RUN: From 1999-2200 (08-26-02)

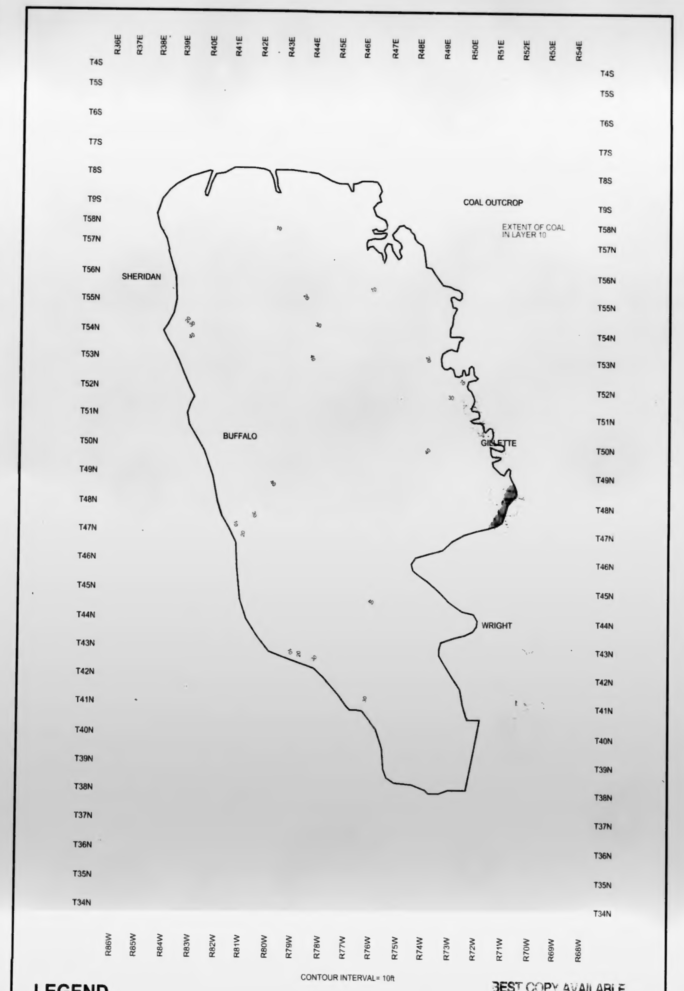
Date: 09/05/02	Drawing File: Figure 4-26_4-29.dwg
Scale: As Noted	Drawn By: ETC

22

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

30 OF 34
12.5X
SUPTDOCS/GPO
MAP 23



CONTOUR INTERVAL= 10ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 10
Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

FIGURE 4-27
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2060

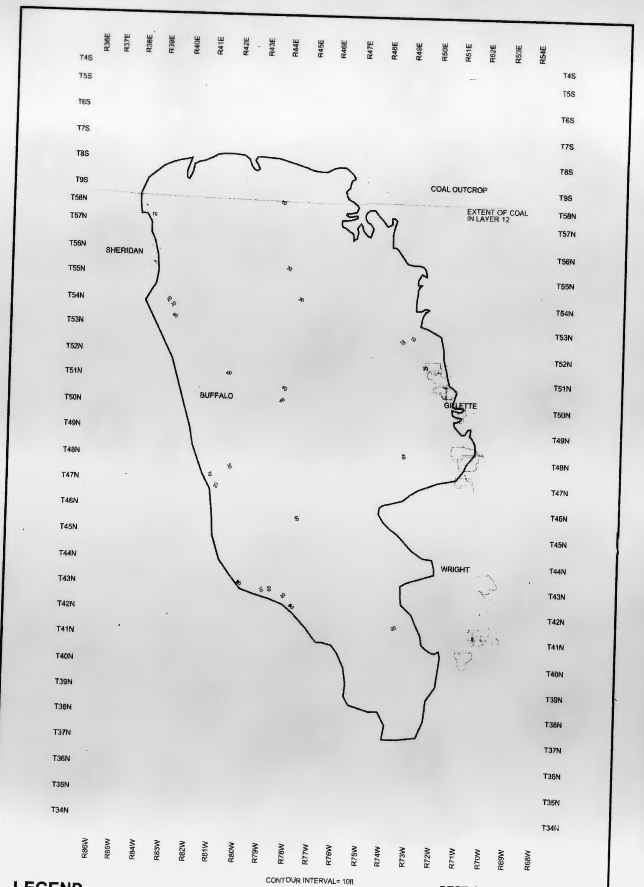
MODEL RUN From 1999-2200 (08-26-02)	
Date 09/05/02	Drawing File Figure 4-26_4-29.dwg
Scale As Noted	Drawn By ETC

23

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

31 OF 34
12.5X
SUPTDOCS/GPO
MAP 24


R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S
T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
COAL OUTCROP
EXTENT OF COAL IN LAYER 12
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
10
20
30
40
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W

CONTOUR INTERVAL= 10ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-28
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 12 YEAR 2060*

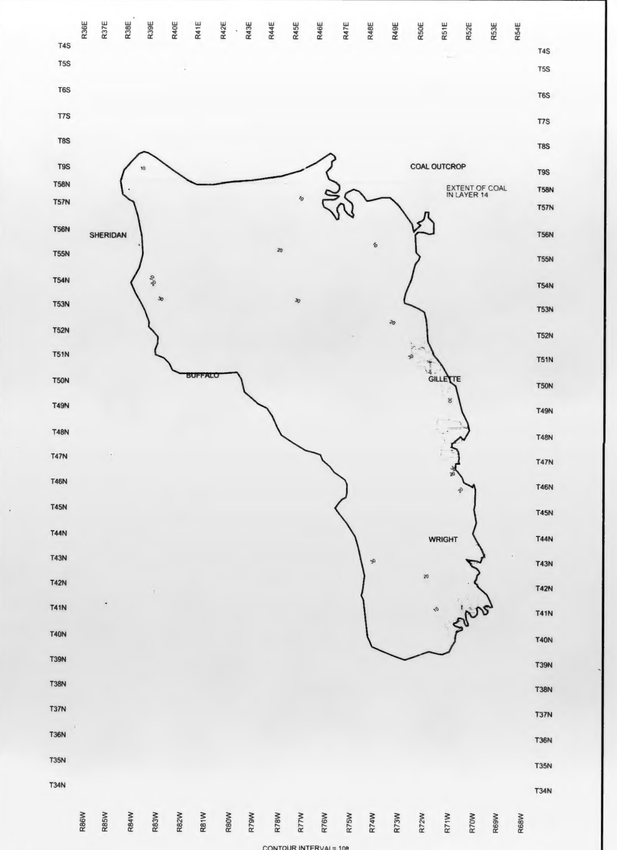
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 4-26_4-29.dwg
Scale: As Noted	Drawn By: ETC

24

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN...,VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

32 OF 34
12.5X
SUPTDOCS/GPO
MAP 25



CONTOUR INTERVAL= 10ft

BEST COPY AVAILABLE

LEGEND

Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 14
▨ Dry Cell
Towns
Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

**POWDER RIVER BASIN
OIL & GAS PROJECT FEIS**

*FIGURE 4-29
MODELED DRAWDOWN UPPER FORT UNION
COALS LAYER 14 YEAR 2060*

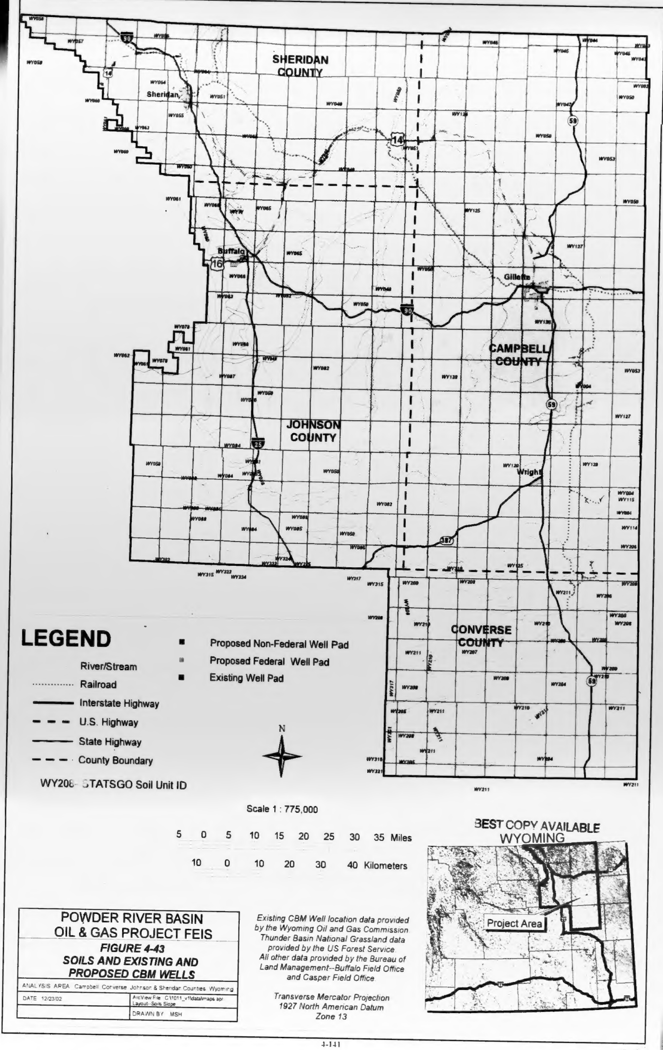
MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 4-26_4-29.dwg
Scale: As Noted	Drawn By: ETC

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....VOLUME 2 OF 4... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

33 OF 34
12.5X
SUPTDOCS/GPO
MAP 26



BEST COPY AVAILABLE

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

FIGURE 4-43
SOILS AND EXISTING AND PROPOSED CBM WELLS

ANALYSIS AREA Campbell, Converse, Johnson & Sheridan Counties, Wyoming
DATE 12/23/02
ArcView File C:\1011_v1\data\maps.apr Layout--Soils Slope
DRAWN BY MSH

Existing CBM Well location data provided by the Wyoming Oil and Gas Commission. Thunder Basin National Grassland data provided by the US Forest Service. All other data provided by the Bureau of Land Management--Buffalo Field Office and Casper Field Office.

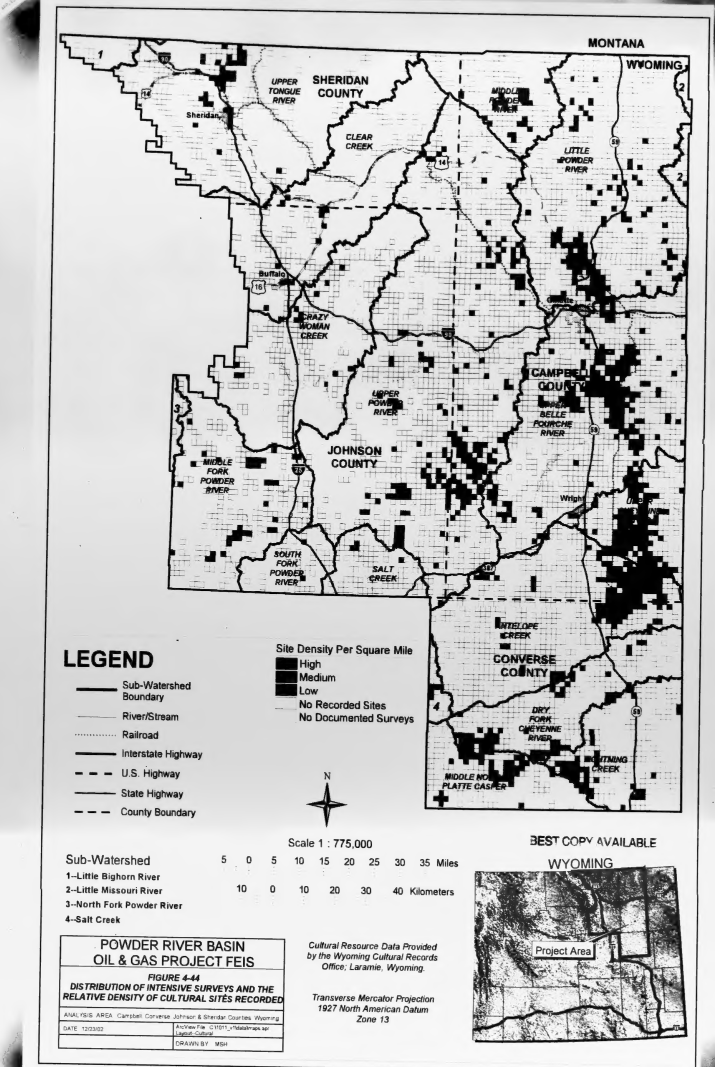
Transverse Mercator Projection
1927 North American Datum
Zone 13

26

I 53.59:P
87/2/FINAL/V.2

FINAL ENVIRONMENTAL IMPACT STATEMENT AND
PROPOSED PLAN....,VOLUME 2 OF 4.... WYOMING
STATE OFFICE... BUREAU OF LAND MANAGEMENT...
U.S. DEPARTMENT OF THE INTERIOR... JANUARY 2003

34 OF 34
12.5X
SUPTDOCS/GPO
MAP 27



BEST COPY AVAILABLE

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

FIGURE 4-44
DISTRIBUTION OF INTENSIVE SURVEYS AND THE RELATIVE DENSITY OF CULTURAL SITES RECORDED

ANALYSIS AREA Campbell Converse Johnson & Sheridan Counties, Wyoming
DATE 12/23/02
ArcView File C:\1011_v1\data\maps.apr Layout--Cultural
DRAWN BY MSH

Cultural Resource Data Provided by the Wyoming Cultural Records Office; Laramie, Wyoming.

Transverse Mercator Projection
1927 North American Datum
Zone 13

27